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Survey of Cadmium Emission Sources

GCA Corp.
Chapel Hill, NC

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

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16. ABSTRACT

This document presents technical data used to support decision making on the need for listing cadmium under Section 108(a)(1), Section 112(b)(1)(A), or Section 111(b)(1)(A) as required by Section 122 of the Clean Air Act, as amended in 1977. Data are presented describing potential sources of cadmium emissions, control techniques used for cadmium emission control, estimated controlled and uncontrolled cadmium emissions, estimated ambient air quality, and compliance status. The results of special dispersion modeling are presented for incineration, interaction of smelters, and for interaction of sources in the New York City - New Jersey area.

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1. EXECUTIVE SUMMARY

This report presents the results of a study to identify and quantify the major nationwide sources of cadmium emissions, and to estimate ambient cadmium concentrations resulting from these emissions. Section 122 of the Clean Air Act Amendments of 1977 requires the Administrator to determine whether atmospheric emissions of cadmium pose a threat to public health. This report will be used in conjunction with the various health effects documents as support for the Administrator's decision regarding the listing of cadmium.

Initial analyses indicated that a clear distinction exists between the major cadmium emission sources and the minor sources. By reviewing available literature, interviewing personnel at Federal, State, and local agencies, and performing several plant visits, the major cadmium emission source categories were identified to be the following: fossil fuel combustion emitting 534 Mg/yr (588 t/yr); primary nonferrous smelters emitting 180-203 Mg/yr (197-222 t/yr); municipal refuse incineration emitting 35 Mg/yr (38 t/yr); iron and steel production emitting 13 Mg/yr (14 t/yr); and wastewater sludge incineration emitting 13 Mg/yr (14 t/yr).

Cadmium emission estimates were developed for these source categories using a variety of methods depending upon the available data. Fossil fuel combustion cadmium emissions were estimated using cadmium emission factors and annual fuel consumption data from the Department of Energy. Primary nonferrous smelters and municipal refuse incineration cadmium emissions were developed through plant by plant analyses. Iron and steel production and sludge incineration cadmium emissions are based upon emission factors and annual throughput for the industry. In addition to estimating annual cadmium emissions, this study also discusses the processes and emission controls currently in use, the geographical distribution and the compliance status of the various industries, and compares the cadmium emission estimates determined in this study to other such estimates from previous studies.

For initial screening purposes, maximum potential ambient cadmium concentrations associated with the major cadmium emission sources were estimated by a "surrogate pollutant" approach by calculating maximum cadmium to particulate and cadmium to lead ratios of the emission streams and multiplying them by the appropriate National Ambient Air Quality Standards (NAAQS) for particulate and lead, respectively. Consequently, the ambient cadmium concentrations estimated by this method correspond to the maximum ambient cadmium levels if sources were allowed emissions which individually result in ambient concentrations equal to the NAAQS's. In actual practice, State regulation of individual sources restrict emissions to levels considerably below those estimated by this method.

The maximum ambient cadmium concentrations predicted by this approach for package incinerators and primary pyrometallurgical zinc smelters were four to ten times higher than predicted for any other category. For these two source categories, dispersion modeling of cadmium emissions was conducted to develop more realistic estimates of ambient cadmium concentrations in the vicinity of sources within these categories. Ambient cadmium concentrations resulting from several emission sources in a geographical area were also estimated by dispersion modeling. Two areas were modeled: a portion of southern Arizona with six copper smelters and the New York City-northern New Jersey metropolitan area which has a large number of fossil fuel-fired power plants and municipal incinerators. In both cases the results of the dispersion modeling compare favorably with measured ambient cadmium concentrations.

In addition to examining the major cadmium emission source categories as determined by annual cadmium emissions, the primary cadmium smelting industry was also examined. Although primary cadmium production is considered a minor cadmium emission source emitting only 1.3 Mg/yr (1.4 t/yr), the high cadmium content of the emission streams could produce ambient cadmium levels higher than some larger sources. The surrogate pollutant approach was not utilized for this source category because the emitted particulate is essentially all cadmium. However, two primary pryrometallurgical cadmium smelters were modeled to determine maximum ambient cadmium concentrations using site specific data.

Table 1-1 presents the cadmium emission sources examined in this study and the associated ambient cadmium concentrations. The concentrations presented in this table correspond to the most refined estimation method.

TABLE 1-1 MAXIMUM ANTICIPATED AMBIENT CADMIUM CONCENTRATIONS

Process	Maximum anticipated ambient cadmium concentration (ng/m^3)	Analysis method
Primary cadmium smelters	261	Dispersion Modeling
Sludge incinerators	128	Surrogate Pollutant
Primary lead smelters	122	Surrogate Pollutant
Primary zinc smelters	108	Dispersion Modeling
Package incinerators	60	Dispersion Modeling
Blast furnaces	44	Surrogate Pollutant
Electric arc furnaces	33	Surrogate Pollutant
Open hearth furnaces	19	Surrogate Pollutant
Coal combustion	19	Surrogate Pollutant
Residual fuel oil combustion	9	Dispersion Modeling
Basic oxygen furnaces	6	Surrogate Pollutant
Primary copper smelters	2	Dispersion Modeling
Municipal incinerators	2	Dispersion Modeling
Sintering	1	Surrogate Pollutant
Coke ovens	0.05	Surrogate Pollutant

2. INTRODUCTION

2.1. PHYSICAL AND CHEMICAL CHARACTERISTICS OF CADMIUM

Cadmium is a relatively rare element in the earth's crust, ranking between mercury and silver in abundance. Cadmium was first discovered in 1817 as an impurity in pharmaceutical zinc carbonate, but was not commercially extracted in the metal form until 1906.[1] The pure form is produced as a byproduct of zinc mining and smelting, from ores with a typical cadmium-to-zinc ratio of 1:200.

Cadmium is a soft, malleable metal which is silver-white in color. The metal has a bright luster which will dull on exposure to moist air due to the formation of a thin coat of cadmium oxide.[1] The properties of cadmium are attributable to its location in the periodic table of the elements. Cadmium is located in Group IIb, Period V of the periodic table along with zinc and mercury (see Figure 2.1-1). The atomic number of cadmium is 48 and the atomic weight is 112.40. Some important properties of cadmium are listed in Table 2.1-1.[2] The metal is ductile, easily soldered, and readily electrodeposited. Because of its position in the electromotive series, it provides galvanic protection as a plating on iron or steel and resists corrosion in seawater.[3]

The melting and boiling points of cadmium are low compared to the metals with which it is associated, as shown in Table 2.1-2. The low melting and boiling points account for the volatility and high vapor pressure of cadmium at moderate temperatures. However, nearly all cadmium and cadmium compounds are in the solid state at the temperature of most gas cleaning systems. The volatility of cadmium is important in air pollution considerations.

Cadmium, as a member of Group IIb, has a stable valence of two. Vaporized cadmium is monatomic and, depending upon conditions, reacts quickly to form the oxide, chloride, sulfate, and other compounds.[3]

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac															

Figure 2.1-1 Periodic table of the elements.

TABLE 2.1-1 PHYSICAL CHARACTERISTICS OF CADMIUM[2]

Crystal structure	Hexagonal pyramids
Hardness	2.0 (Moh's scale)
Ductility	Considerable
Density	
20°C (68°F)(solid)	8.65 g/cm^3
330°C (626°F)(liquid)	8.01 g/cm^3
Melting point	321°C (610°F)
Boiling point	767°C (1412.6°F)
Specific heat	
25°C (77°F)(solid)	0.055 g-cal/g
Electrochemical equivalent	
Cd++ion	0.582 mg/coulomb

TABLE 2.1-2 COMPARATIVE MELTING AND BOILING POINTS[3]

	Melting point		Boiling point	
	°C	°F	°C	°F
Cadmium	321	610	767	1413
Zinc	420	788	907	1665
Lead	327	621	1620	2948
Copper	1083	1981	2336	4237
Iron	1375	2507		
Cadmium Sulfate	1000	1832		
Cadmium Chloride	568	1054	960	1760
Cadmium Oxide	Sublimes at 1559°C (2838°F)			

Naturally occurring compounds such as cadmium sulfide (CdS), cadmium carbonate ($CdCO_3$), cadmium oxide (CdO), and cadmium hydroxide ($Cd(OH)_2$) have extremely low solubility in water. The amount of cadmium which remains dissolved in natural waters is conseouently quite low. Most cadmium found in aquatic systems is associated with suspended solids.[4]

2.2 MULTIMEDIA NATURE OF CADMIUM EXPOSURE

2.2.1 General

This section discusses the nature of human exposure to cadmium from the food chain, the ambient air, and drinking water. Cadmium is released into the environment from several major sources, and follows pathways through the air, soil, or water before contacting humans. Man is exposed to cadmium by inhaling cadmium in the air, eating cadmium in foods, drinking cadmium in water, and by smoking tobacco. The major sources of cadmium, transport pathways, and sources of human exposure to cadmium are diagramed in Figure 2.2-1.[5] The most important pathways are emphasized by the wider lines.

The major potential for exposure to cadmium occurs through the food chain by soil contamination from the application of phosphate fertilizers, wastewater sludge from publicly owned treatment works (POTWs), and from fallout and washout of air emissions.[6] About 85.5 percent of normal daily retention is caused by ingestion of cadmium in food. For smokers, cigarettes have the potential of being the second greatest source of exposure, depending on how many packs are smoked per day.[7] Drinking water is the second greatest source of cadmium for non-smokers, causing about 10 percent of the normal daily retention. Breathing ambinet air ranks lowest as a source of exposure, accounting for about four percent of normal daily retention. The percent of cadmium intake from food, air, and drinking water is presented in Table 2.2-1.[8]

2.2.2 Cadmium Exposure Through Food

The major pathway of cadmium contamination of food is uptake of cadmium from the soil by edible plants. Cadmium exposure takes place when the plants are eaten by man. Table 2.2-2[9] shows that as the concentration of cadmium increases in neutral soil, the concentration of cadmium increases in the edible portion of food crops. In general, the relative cadmium content of the

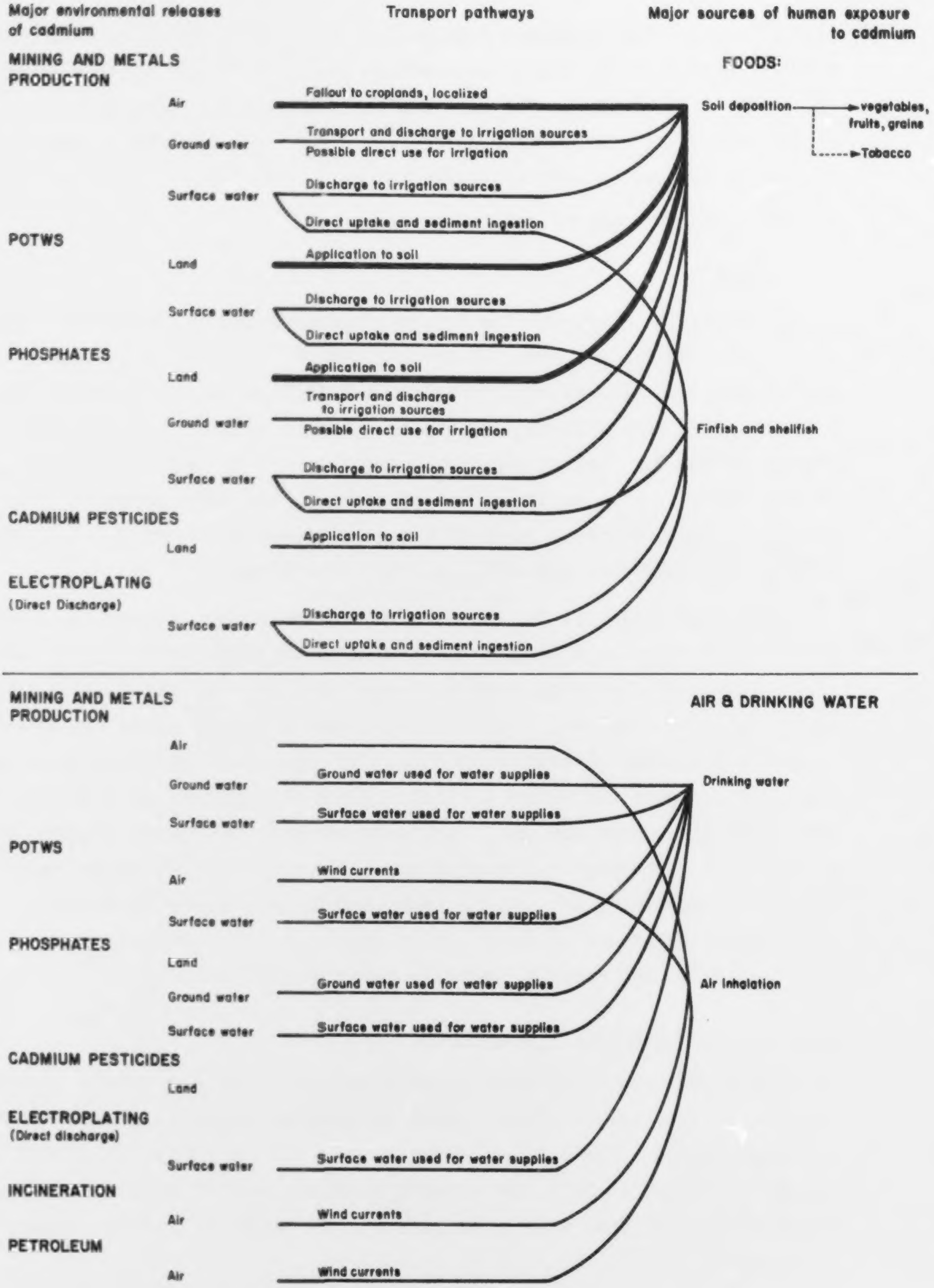
Major environmental releases of cadmium
Transport pathways
Major sources of human exposure to cadmium
MINING AND METALS PRODUCTION
Air
Fallout to croplands, localized
Ground water
Transport and discharge to irrigation sources
Possible direct use for irrigation
Surface water
Discharge to irrigation sources
Direct uptake and sediment ingestion
POTWS
Land
Application to soil
Surface water
Discharge to irrigation sources
Direct uptake and sediment ingestion
PHOSPHATES
Land
Application to soil
Ground water
Transport and discharge to irrigation sources
Possible direct use for irrigation
Surface water
Discharge to irrigation sources
Direct uptake and sediment ingestion
CADMIUM PESTICIDES
Land
Application to soil
ELECTROPLATING (Direct Discharge)
Surface water
Discharge to irrigation sources
Direct uptake and sediment ingestion
FOODS:
Soil deposition
vegetables, fruits, grains
Tobacco
Finfish and shellfish
MINING AND METALS PRODUCTION
Air
Ground water
Ground water used for water supplies
Surface water
Surface water used for water supplies
POTWS
Air
Wind currents
Surface water
Surface water used for water supplies
PHOSPHATES
Land
Ground water
Ground water used for water supplies
Surface water
Surface water used for water supplies
CADMIUM PESTICIDES
Land
ELECTROPLATING (Direct discharge)
Surface water
Surface water used for water supplies
INCINERATION
Air
Wind currents
PETROLEUM
Air
Wind currents
AIR & DRINKING WATER
Drinking water
Air inhalation

Figure 2.2-1 Transport pathways for cadmium.[5]

TABLE 2.2-1 MEDIA CONTRIBUTIONS TO NORMAL RETENTION[8]

Medium	Percent of total retention No smoking	1 pack/day	3 packs/day
Ambient air	4.3	3.0	1.9
Water	10.2	7.3	4.7
Food	85.5	61.0	38.8
Cigarettes	0.0	28.7	54.6

TABLE 2.2-2 CADMIUM IN FOOD CROPS GROWN IN SOILS OF VARYING CADMIUM CONTENT[9]

Crop (edible portion)	Cadmium (ppm) in plants grown in soil with the following concentration of cadmium: BDL[a]	2.5 ppm	5 ppm
Oats	0.21	1.50	2.07
Soybeans	0.29	1.88	2.51
Lettuce	0.66	7.22	10.36
Carrots	0.24	2.53	2.65
Potatoes	0.18	0.89	1.09
Tomatoes	0.23	0.99	1.03

[a] BDL - Below detectable limits.

four main categories of food appears to represent a concentrating of cadmium as it passes up the food chain. Fruits and vegetables have the lowest cadmium content, followed by grains and cereals, then dairy products, and finally meats and seafoods, which contain twenty to a hundred times more cadmium than the lower food levels.[10] Tobacco is a plant which is consumed by smoking and which is very efficient at absorbing cadmium from soils. When tobacco is smoked, a portion of the cadmium is inhaled and deposited in the lungs.

The major means by which cadmium is deposited on soil are by phosphate fertilizers, application of sludge, and air emissions. Phosphate fertilizers produced from phosphate rock are applied to agricultural land in all fifty states. The phosphate ores used in the manufacture of fertilizer vary in cadmium content from 3 to 100 ppm depending on the geographical location of the phosphate mines.[11]

The application of sludge from publically owned treatment works to crop land represents another source of cadmium contamination of soil used to grow food. The concentration of cadmium in sludge varies widely. Industrial sludge contains as much as 3,400 ppm cadmium while residential sludge contains about one to five ppm.[12] Sludge is applied to soil to replace micronutrients and to add organic matter to the soil.

Releases of cadmium to the air may cause an increase in the level of cadmium in nearby soils. Airborne cadmium travels downwind from the source, settling onto soil. Air releases of cadmium occur from incineration of plastics and pigments, the burning of fossil fuels such as coal and petroleum and the smelting of primary nonferrous metals.[13]

2.2.3 Cadmium Exposure from Ambient Air

The ambient concentration of cadmium, as with any air pollutant, varies depending upon the location. Since cadmium usually occurs in the particulate form, it is susceptible to settling, impaction, rainout, and other natural means of removal from the air. Cadmium in the atmosphere is mainly in the form of suspended aerosol particles such as oxides, chlorides, or sulfates.[14] Larger particles settle out very quickly, while smaller ones remain airborne for long periods of time and are transported greater distances by wind or diffusion. Cadmium concentrations in the atmosphere in the United States are, with very few exceptions, of the order of a few hundredths or thousandths of micrograms per cubic meter of air.[15]

2.2.4 Cadmium Exposure from Drinking Water

A minor source of cadmium exposure is through contaminated drinking water. The level of cadmium in drinking water is expected to be low because drinking water regulations limit cadmium concentration to 0.01 micrograms per liter, and because wells supplying drinking water are in aquifers not likely to be contaminated.[16] In areas not known to be polluted by cadmium, the concentration in water is less than one part per billion, both in natural waters and drinking water. Cadmium is relatively insoluble and will precipitate out of water into sediment.

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11. Reference 5, p. 6-4.
12. Reference 5, p. 6-11.
13. Reference 5, p. 6-18.
14. Reference 4, p. 3-3.
15. Reference 4, p. 2-15.
16. Reference 5, p. 6-38.

3. USES OF CADMIUM

3.1 INTRODUCTION

The United States is the largest consumer of cadmium in the world, using slightly more than one-fourth of the total world refined production. Nearly 5,000 megagrams (5,500 tons) of cadmium were used in the U.S. in 1979. About two-thirds of U.S. cadmium demand in 1979 was met by imported metal and ores.[1]

There are four major uses of cadmium, all of which are dissipative. Figure 3-1 shows the percentage of cadmium consumed in the U.S. for each of the major uses. According to estimates, approximately 51 percent of the cadmium consumed by the United States in 1979 was used for electroplating.[1] The manufacture of batteries required about 22 percent of the national consumption of cadmium in 1979, while pigments required about 13 percent. The fourth major use of cadmium in 1979 was for the manufacture of plastic stabilizers, which accounted for 11 percent of the cadmium used in 1979. Miscellaneous uses account for the remaining three percent.

In the future, the relative percentage of cadmium used in the major applications is expected to change. The manufacture of batteries and pigments are expected to require a larger share of the cadmium used than is presently consumed. Electroplating will require a smaller percentage of the market, but actual tonnage consumed for electroplating should remain constant. The total amount of cadmium used in the United States is expected to increase by as much as fifty percent by the year 2000.[2]

3.2 ELECTROPLATING

Cadmium has several properties which have led to its widespread use in electroplating. A very thin coating of cadmium on iron and steel provides excellent protection from corrosion. Cadmium is widely used for plating motor vehicle parts, aircraft parts, marine equipment, hardware, household applicances,

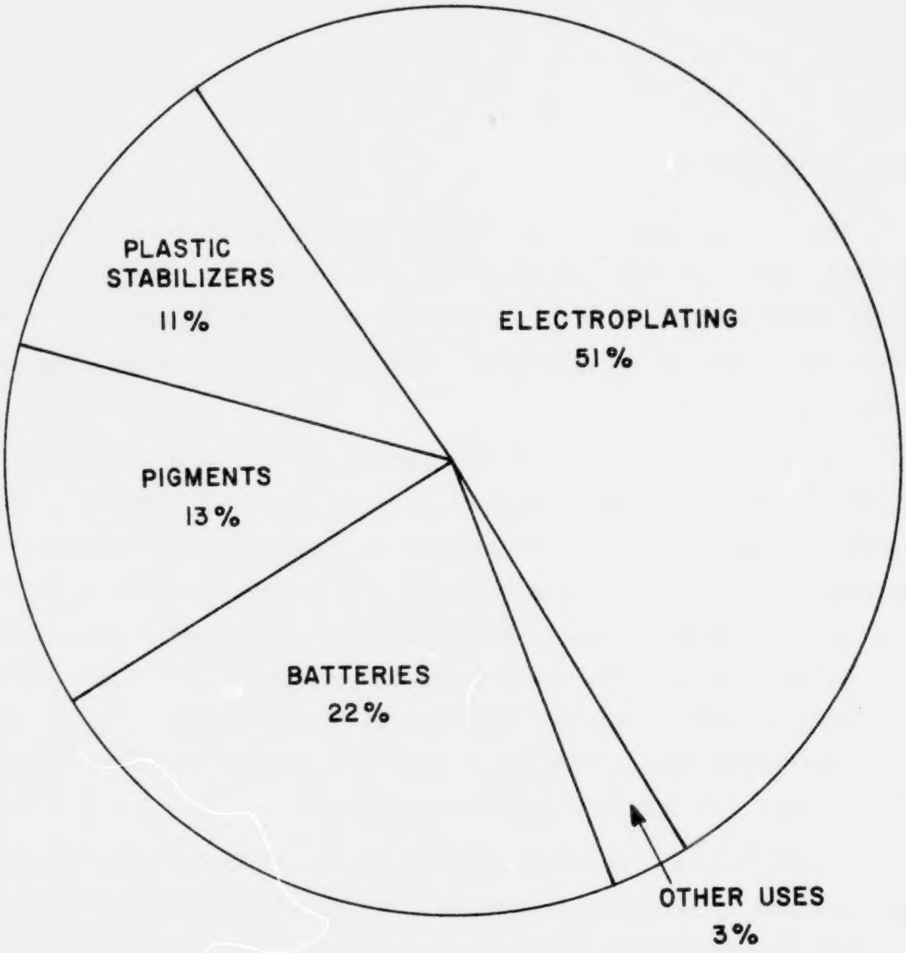

Figure 3-1 U.S. cadmium consumption, 1979.[1]

and miscellaneous industrial machinery parts to prevent corrosion.[3] Cadmium coatings have special resistance to the corrosive effects of seawater and alkalies, making cadmium an excellent plating material for marine applications. It is possible to obtain uniform deposition on intricately shaped objects, and the coating tends to maintain a lustrous appearance for long periods of time. Electrical contacts which are plated with cadmium have a low electrical resistance. Cadmium-plated parts are easily soldered. In addition, cadmium plating has little effect on the strength of steel parts stressed in high-temperature service.[3]

Of all cadmium applications, electroplating seems to be the primary one for which alternative materials are not available. No substitute can entirely reproduce the properties of cadmium plate, particularly its lustrous appearance.[4] Zinc can be substituted for cadmium in electroplating except for applications in alkaline environments, or where the plate must be very thin, or where solderability or ductility of the plated surface is important.

3.3 PIGMENTS

Cadmium is used as a pigment in water-base paints, plastics, rubber, inks, ceramic glazes, glass, textiles, enamels, and artists' colors. About 75 percent of cadmium pigments are used to color plastic.[5] Because cadmium pigments are non-bleeding and alkali-resistant, they are particularly suitable for plastic automobile interior parts. The high-temperature stability of cadmium pigments makes them desirable for high temperature plastic molding operations.

The principal compounds used are cadmium sulfide or cadmium sulfoselenide. Cadmium sulfide produces colors yellow to light orange, while cadmium sulfoselenides produce colors orange to deep maroon. These primary pigments are used or mixed with mercury, zinc, or barium compounds. Cadmium compounds have outstanding covering power, good stability against heat, light, and moisture, and good chemical resistance.

The best substitutes for cadmium in pigments are other inorganic compounds. Certain hydrate ferric oxides and lead and zinc chromates can be substituted for yellows, but they lack the heat stability in high temperature plastic molding operations. Ferric oxides can be substituted for cadmium reds, but they are not as brilliant.[6]

3.4 PLASTIC STABILIZERS

Cadmium salts of long-chain organic acids are used as stabilizers for plastics. These stabilizers halt or slow the discoloration of polyvinyl chloride (PVC) caused by the breakdown of PVC resin during molding. Stabilizers containing cadmium are used in almost every plastic material except plastics used for food packaging.

Organo-tin compounds can be used as substitutes for cadmium compounds in plastic stabilizers, but they are more expensive than cadmium compounds. Stabilizers of calcium-zinc composition are competitive in terms of both performance and cost, and may replace cadmium in some stabilizer applications in the future.

3.5 BATTERIES

Another major use of cadmium is in the manufacture of batteries. The nickel-cadmium battery is the most prominent application in this category. Some cadmium is used to make silver-cadmium batteries, where performance is more important than cost.[7] Nickel-cadmium batteries are initially more expensive than lead storage batteries, but have a lifetime at least three times that of the lead-acid battery. The principal use in the United States is for small batteries of a sealed cell design because the batteries can be repeatedly charged and discharged without buildup of internal pressure. The nickel-cadmium battery is used in alarm systems, pacemakers, portable appliances and tools, and calculators.

3.6 MISCELLANEOUS USES

Cadmium is used in a large number of miscellaneous applications. In 1979 and 1980, over 500 cadmium-related patents were issued worldwide. Cadmium is an ingredient in alloys (primarily low-temperature solder), silver brazes, and a special copper alloy used in automobile radiators. Silver-cadmium alloys are used in making nuclear reactor control rods. Cadmium phosphates are used for television tubes and fluorescent tubes. Silver-cadmium oxide is used for electrical contacts in motor starting switches, relays, and circuit breakers. Small amounts of cadmium are used in rubber catalysts, fungicides, superconductors, lubricants, radiation detectors, leather tanning, and solar cells.

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4. SOURCES OF ATMOSPHERIC CADMIUM

4.1 INTRODUCTION

This section presents information on the major source categories of cadmium emissions. The contribution to nationwide cadmium emissions by the major cadmium emission sources, fossil fuel combustion, primary nonferrous smelters including cadmium production, municipal refuse incineration, sludge incineration, and iron and steel production, is shown in Table 4.1-1. This section presents process descriptions, geographical distributions, emission control techniques, emissions estimates, compliance status, and a comparison of the national emission estimates with other studies for all the major cadmium emission sources.

In addition to the major cadmium emission sources, a number of minor sources exist. The minor sources include motor oil combustion, rubber tire wear, pigment manufacturing, plastic stabilizer manufacturing, battery manufacturing, cement manufacturing, and fertilizer and fungicide application. The annual cadmium emissions from these sources are considered small and consequently were not examined in this study.

TABLE 4.1-1 ESTIMATED ANNUAL CADMIUM EMISSIONS OF MAJOR SOURCE CATEGORIES

Source	Annual uncontrolled emissions		Annual controlled emissions		Percentage of total controlled emissions
	Mg/yr	t/yr	Mg/yr	t/yr	
Fossil Fuel Combustion					
Coal	997	1,100	183	202	
Residual oil	330	363	314	345	
Distillate oil	16.5	18.2	16.5	18.2	
Kerosene and jet fuel	6.1	6.7	6.1	6.7	
Aviation and motor gasoline	14.5	16	14.5	16	
Total	1,364	1,504	534	588	68.1
Primary Nonferrous Smelters					
Primary zinc smelters	ND	--	4.2	4.6	
Primary lead smelters	ND	--	74 - 97	82 - 107	
Primary copper smelters	ND	--	101	111	
Primary cadmium smelters	ND	--	1.3	1.4	
Total			180 - 204	197 - 224	24.2
Municipal Refuse Incineration					
Conventional incinerators	142	159	31.2	34.3	
Package incinerators	ND	--	3.6	4.0	
Total			34.8	38.3	4.4
Wastewater Sludge Incineration	73	80	13	14.4	1.7
Iron and Steel Industry					
Basic oxygen furnaces	114	126	4.6	5.0	
Electric arc furnaces	106	117	3.2	3.5	
Open hearth furnaces	54	59	2.7	3.0	
Sintering	22	25	2.0	2.3	
Blast furnaces	18.7	20.8	Tr	Tr	
Coking	22	24	Tr	Tr	
Miscellaneous	Tr	Tr	Tr	Tr	
Foundries	3.7	4.1	0.08	0.09	
Total	340.4	375.9	12.58	13.89	1.6
Total			787.2	865.0	100.0

Tr = Trace
ND = No data for estimate

4.2 FOSSIL FUEL COMBUSTION

4.2.1 Introduction

Over 92 percent of United States energy consumption is generated by fossil fuel sources. With the exception of natural gas, cadmium is found in all of fossil fuels. Calculations indicate that as a group, coal-fired and oil-fired power plants, and residual oil, distillate oil, gasoline, and kerosene combustion are the largest sources of atmospheric cadmium emissions, approximately 534 Mg (588 tons) in 1979.

4.2.2 Fossil Fuel Usage

Combustion of fossil fuel containing cadmium occurs in all sectors of the U.S. economy: utility, industrial, commercial, residential and transportation. A brief discussion of each sector is presented below.

In 1979, electric utilities accounted for 78 percent of the coal consumed and approximately 8 percent of the petroleum products consumed.[1] Over 99.8 percent of the coal consumed was bituminous or lignite. Less than 0.2 percent of the coal was anthracite. About 87 percent of the petroleum product consumed was residual oil for oil-fired power plants. Another 12 percent was distillate oil used for start-up of coal and oil-fired power plants and in gas turbines. The electric utility sector also used 0.8 percent of the total jet fuel production.

The industrial, commercial, and residential sectors burn fossil fuels to meet heating needs. Hot water and steam boilers provide the majority of industrial and commercial heat, while hot-air furnaces burning distillate oil are used for space-heating in all three sectors. Commercial equipment is normally classified in the capacity range of 0.21 to 8.8 gigajoules per hour (0.2 to 8 million BTU per hour). Industrial heating equipment is normally classified in the capacity range of 8.8 to 707 gigajoules per hour (8 to 700 million BTU per hour).

In 1979, 1.3 percent of the total coal consumption was in the residential and commercial sectors, and 21 percent of the total coal consumption was in the industrial sector. The commercial sector accounted for 15 percent of the residual fuel oil consumption, and the industrial sector accounted for 21 percent. The residential and commercial sectors combined accounted for 45 percent of the total distillate fuel oil consumption and the industrial sector accounted for 16 percent. The residential and commercial sectors used nearly 69 percent of the kerosene produced in 1979 with the industrial sector accounting for the remainder.

The transportation sector includes both on-highway and off-highway, railroad, shipping, and aviation fuel usage. For coal, sales to railroad and vessels accounted for less than 0.01 percent of total 1979 consumption. In 1979, the 16 percent of the total residual fuel oil which went to transportation was consumed by the shipping industry. Distillate fuel oil consumption in the transportation sector consists of on-highway diesel, off-highway diesel, railroads and shipping. Transportation accounted for 36 percent of total distillate fuel oil usage in 1979. The transportation sector consumed 99 percent of the total jet fuel, 100 percent of the total aviation gasoline, and 98 percent of the motor gasoline in 1979.[1]

4.2.3 Geographical Distribution

Fossil fuel combustion is distributed all over the United States. Regional per capita energy consumption rankings vary depending upon the sector. For the residential/commercial sector, highest per capita consumption occurs in the Mountain and New England States; lowest per capita consumption occurs in the South Atlantic and East South Central States. For the industrial sector, the West South Central States have the highest and New England States have the lowest per capita consumption. Highest per capita consumption in the transportation sector occurs in the West South Central and Mountain States; lowest per capita consumption takes place in the New England and Middle Atlantic States.[2]

4.2.4 Emission Control Techniques

In the utility and industrial sectors, control of particulate emissions at coal-fired plants involves electrostatic precipitators (ESP), cyclones, scrubbers, or fabric filters. In the commercial sector, ESPs or cyclones are used or boilers are uncontrolled. Where SO_x control is required, the choice of method may affect the particulate control. Plants which use flue gas desulfurization scrubbers usually use venturi scrubbers for particulate control. Tables 4.2-1, 4.2-2, and 4.2-3 present the percentage usage of each control device for all coal-consuming sectors except transportation. Control devices are not generally used in the transportation sector.

Among plants and vehicles that burn residual or distillate oil, only utility sector boilers use control devices to reduce particulate emissions. Normal options include cyclones, scrubbers, or ESPs. Particulate emissions from oil-fired plants are dependent on the grade of fuel fired, with heavier grades resulting in higher particulate emissions. Tables 4.2-4 and 4.2-5 present the percentage of utility sector plants using control devices.

4.2.5 Emissions

Table 4.2-6 presents the annual cadmium emissions from fossil fuel combustion. Based on the fossil fuel supplied in 1979, 534 Mg (588 tons) of cadmium were emitted into the atmosphere. Cadmium emissions were estimated using Department of Energy data[1] on fuel supplied to sectors of the U.S. economy, and calculated nationwide average cadmium emission factors for each fuel type and sector. The calculation required percentage breakdowns by fuel type, burner type, and control device.

Table 4.2-1 presents the emission factor calculations for utility sector coal combustion. Emission factors specific for fuel type, control device, and burner type were multiplied by percent usage of control device and percentage of total coal assigned to burner type. The resulting weighted emission factors were totaled to give a nationwide average emission factor weighted by coal usage. Since lignite stokers and anthracite-fired boilers account for only 0.35 percent of utility sector coal consumption, their emissions were not included in the cadmium emission calculations. Tables 4.2-2 and 4.2-4 present the similar calculations for industrial sector coal and residential/commercial sector coal, respectively.

TABLE 4.2-1 CALCULATION OF CADMIUM EMISSION FACTORS FOR UTILITY COAL

Coal type, burner type, control device	Percent of coal burned	Percent of control device	Emission factor		Weighted emission factor	
			pg/J	(#/10^{12} Btu)	pg/J	(#/10^{12} Btu)
Bituminous (95.8%)						
Pulverized dry bottom	73					
ESP		83	1.7	(3.8)	1.03	(2.40)
Centrifugal		11	24	(54)	1.93	(4.49)
Other[a]		5	2.8	(6.3)	0.10	(0.23)
No control		1	80	(179)	0.58	(1.36)
Pulverized wet bottom	11					
ESP		77	1.4	(3.1)	0.12	(0.28)
Centrifugal		9	19	(42)	0.19	(0.44)
Other		7	2.6	(5.8)	0.02	(0.05)
No control		7	73	(163)	0.56	(1.31)
Cyclone	11					
ESP		89	0.3	(0.7)	0.03	(0.07)
Centrifugal		5	4.0	(8.9)	0.02	(0.05)
Other		3	0.5	(1.1)	0.002	(0.005)
No control		3	13	(29)	0.04	(0.09)
Stokers	0.82					
ESP		44	1.3	(3.0)	0.005	(0.01)
Centrifugal		25	18	(42)	0.04	(0.09)
Other		14	2.2	(5.1)	0.003	(0.007)
No control		16	61	(142)	0.08	(0.19)
Lignite (4.2%)						
Pulverized	3.4					
ESP		100	0.2	(0.5)	0.007	(0.02)
Cyclone	0.72					
Scrubber		100	1.0	(2.3)	0.007	(0.02)
Stokers	0.082[b]					
Anthracite (0.27%)						
Pulverized	0.096[b]					
Stokers	0.17[b]					
NATIONWIDE AVERAGE CADMIUM EMISSION FACTOR FOR COAL-FIRED POWER PLANTS					4.8	(11.1)

[a] Other - scrubber, fabric filter, etc.

[b] Insignificant contribution.

References 3, 4.

TABLE 4.2-2 CALCULATION OF CADMIUM EMISSION FACTORS FOR INDUSTRIAL COAL

Coal type, burner type, control device	Percent of coal burned	Percent of control device	Emission factor		Weighted emission factor	
			pg/J	(#/10^{12} Btu)	pg/J	(#/10^{12} Btu)
Bituminous (100%)						
Pulverized	60					
ESP		28	1.7	(4.0)	0.29	(0.67)
Centrifugal		45	24	(56)	6.48	(15.07)
Scrubber		8	2.8	(6.5)	0.13	(0.30)
No control		19	80	(186)	9.12	(21.21)
Stokers	40					
Centrifugal		53	18	(42)	3.82	(8.89)
No control		47	61	(142)	11.47	(26.68)
NATIONWIDE AVERAGE CADMIUM EMISSION FACTOR FOR INDUSTRIAL SECTOR COAL COMBUSTION					31	(73)

References: 3, 4.

TABLE 4.2-3 CALCULATION OF CADMIUM EMISSION FACTOR FOR RESIDENTIAL/COMMERCIAL COAL

Coal type, burner type, control device	Percent of coal burned	Percent of control device	Emission factor pg/J	Emission factor (#/10^{12} Btu)	Weighted emission factor pg/J	Weighted emission factor (#/10^{12} Btu)
Bituminous (64%)						
Pulverized	14					
ESP		40	1.7	(4.0)	0.10	(0.22)
No control		60	80	(186)	6.7	(15.6)
Stokers	50					
Centrifugal		20	18	(42)	1.8	(4.2)
No control		80	61	(142)	24	(55.8)
Anthracite (36%)						
Stokers	36					
Centrifugal		20	0.22	(0.51)	0.02	(0.05)
No control		80	0.73	(1.70)	0.21	(0.49)
	NATIONWIDE AVERAGE CADMIUM EMISSION FACTOR FOR RESIDENTIAL/COMMERCIAL SECTOR COAL COMBUSTION				33	(76)

References: 3, 4.

TABLE 4.2-4 RESIDUAL OIL CADMIUM CONCENTRATION FACTORS

Sector, control	Percent of plants	Cadmium concentration, ppmw[a]	Weighted cadmium concentration, ppmw[a]
Utility			
Controlled	40	1.15	.46
Uncontrolled	60	2.3	1.38
Concentration factor for residual oil in utility sector			1.8
Industrial			
Uncontrolled	100	2.3	2.3
Concentration factor for residual oil in industrial sector			2.3
Commercial			
Uncontrolled	100	2.3	2.3
Concentration factor for residual oil in commercial sector			2.3
Transportation			
Uncontrolled	100	2.3	2.3
Concentration factor for residual oil in transportation sector			2.3

[a] Parts per million by weight.

References: 3, 4, 5.

TABLE 4.2-5 DISTILLATE OIL CADMIUM CONCENTRATION FACTORS

Sector, control	Percent of plants	Cadmium concentration, ppmw[a]	Weighted cadmium concentration, ppmw[a]
Utility			
Controlled	40	0.05	0.02
Uncontrolled	60	0.1	0.06
Concentration factor for distillate oil in utility sector			0.08
Industrial			
Uncontrolled	100	0.2	0.1
Concentration factor for distillate oil in industrial sector			0.1
Commercial/Residential			
Uncontrolled	100	0.2	0.1
Concentration factor for distillate oil in commercial/residential sector			0.1
Transportation			
Uncontrolled	100	0.1	0.1
Concentration factor for distillate oil in transportation sector			0.1

[a] Parts per million by weight.

References: 3, 4, 6.

TABLE 4.2-6 ANNUAL CADMIUM EMISSIONS FROM FOSSIL FUEL COMBUSTION

Fossil fuel	Fuel supplied in 1979 10^6 bbls[a]	Annual cadmium emissions Mg/yr	(TPY)
Coal			
Utility	528.8[b]	57	(63)
Industrial	143.0[b]	118	(130)
Commercial/residential	9.1[b]	8.0	(8.8)
Transportation	<.05[b]	-	-
Total	681[b]	183	(202)
Residual Oil			
Utility	493	133	(146)
Industrial	214	73	(80)
Commercial	152	53	(58)
Transportation	161	55	(61)
Total	1020	314	(345)
Distillate Oil			
Utility	70	.77	(.85)
Industrial	191	2.6	(2.9)
Commercial/residential	513	7.1	(7.8)
Transportation	432	6.0	(6.6)
Total	1206	16.5	(18.2)
Kerosene and Jet Fuel			
Utility	3	-	-
Industrial	20	-	-
Commercial/residential	44	0.9	(1.0)
Transportation	387	5.2	(5.7)
Total	454	6.1	(6.7
Aviation and Motor Gasoline			
Industrial	31	-	-
Commercial/residential	20	-	-
Transportation	2529	14.5	(16)
Total	2580	14.5	(16)
ANNUAL CADMIUM EMISSIONS TOTAL		534	(588)

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[a] Unless otherwise noted.

[b] Units for "Fuel Supplied in 1979" are Teragrams (Million short tons).

References: 1.

Tables 4.2-4 and 4.2-5 present the comparable calculations for residual oil and distillate oil, respectively. No data were available on actual measurements of cadmium emissions from oil-fired boilers, so uncontrolled cadmium emissions were estimated by assuming that all cadmium present in the fuel leaves the boiler in the flue gas. For controlled emissions, controls have been reported to average 50 percent cadmium removal efficiency.[3] Weighted cadmium concentrations in the fuel oil were calculated to estimate an average cadmium concentration factor for each fuel in each sector.

Appendix B-1 presents an example of the calculations used to develop annual cadmium emissions for coal combustion presented in Table 4.2-1. Appendix B-2 shows a similar example for residual oil and distillate oil cadmium emissions. Appendix B-3 indicates the calculation method for estimating cadmium emissions from kerosene, jet fuel, aviation gasoline, and motor gasoline. Because no actual measurements of cadmium emissions are available, emission factors from the Energy and Environmental Analysis Report[6] are used.

4.2.6 Compliance Status*

EPA established a new source performance standard in 1971 which limits particulate emissions to a maximum of 43 nanagrams/J (0.1 lb/MM BTU). This standard was revised to 13 nanograms/J (0.03 lb/MM BTU) in 1979. Particulate standards range from a low of 9 nanograms/J (0.02 lb/MM BTU) in Arizona, District of Columbia, Nevada, and Vermont for plants larger than 10.6 terajoules/hr (10,000 MM BTU/hr) to a high of 340 nanograms/J (0.8 lb/MM BTU) for small plants in Indiana, Iowa, and North Dakota. The emission standards of most states for larger facilities range from 43 to 130 nanograms/J (0.1 to 0.3 lb/MM BTU). Emission regulations for smaller plants are generally between 86 to 260 nanograms/J (0.2 to 0.6 lb/MM BTU).[7]

The 1980 Report of the Council on Environmental Quality[8] presents the compliance status of 700 major coal-or oil-fired power plants. Eighty percent or 559 plants were in compliance with emissions limitations. Eighteen percent or 124 plants were violating emission limitations and compliance schedules. Seventeen plants were listed as "status unknown". No data were available on industrial and commercial heating plant compliance with state regulations.

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

4.2.7 Comparison of National Emission Estimate with Other Studies

Measurements of cadmium emissions and cadmium content in fuels, and distributions by fuel consumption of control devices and burner types were combined to calculate annual cadmium emissions from fossil fuel combustion of 534 Megagrams (588 tons). In previous studies, Energy and Environmental Analysis (EEA) estimated 68 Mg (75 tons), Oak Ridge National Laboratory estimated 131-1000 Mg (145-1100 Tons), EPA estimated 180 Mg (198 tons); and Sargent estimated 118 Mg (130 Tons).[6]

Higher fuel consumption in recent years accounts for a portion of the discrepancy between the estimates. As an example, the EEA study shows coal consumption at power plants to be 3.56×10^8 Mg (3.91×10^8 tons) of coal. This study uses the 1979 value of 4.8×10^8 Mg (5.28×10^8) tons of coal for power plants plus an additional 1.38×10^8 Mg (1.52×10^8) tons in the industrial, commercial/residential and transportation sectors.

Another difference between EEA's emission estimates and those reported in this study reflect differences in applicability of control devices to residual oil-fired utilities. EEA assumed that 99 percent of these plants are controlled with cyclones.[6] In this study control device applicability in this industry sector was estimated to be only 40 percent based on a 1981 EPA report.[3] The referenced report also estimated a 50 percent efficiency for installed control devices.

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4.3 PRIMARY NON-FERROUS SMELTERS

Cadmium is found as an impurity in zinc, lead and copper ore deposits. Zinc ores contain the highest concentrations of cadmium; concentrations in lead and copper ores are much lower. Airborne cadmium emissions result from the volatilization of this impurity during the pyrometallurgical processing of these ores.

This section examines the airborne cadmium emissions associated with the domestic production of zinc, lead, copper and cadmium. The annual controlled cadmium emissions estimated for these sources are summarized in Table 4.3-1

TABLE 4.3-1 ANNUAL CADMIUM EMISSIONS FROM NON-FERROUS SMELTERS

Source category	Cadmium emissions Mg/yr	Cadmium emissions t/yr
Zinc	4.2	4.6
Lead	74-97	82-107*
Copper	101	111
Cadmium	1.3	1.4

*The range in the annual cadmium emission estimate for lead smelters is due to the uncertainty associated with the fugitive emission estimate for this source category.

Only controlled emissions estimates are reported in this section because the data acquired for these industries are for controlled sources. The scarcity of uncontrolled emissions data and reliable control efficiencies did not warrant calculation of uncontrolled emissions. The methods used to calculate controlled cadmium emissions in order of decreasing reliability are: smelter specific cadmium stack test data; cadmium/particulate ratios applied to particulate emissions estimates; and emission factors for cadmium emissions for various process operations relating cadmium emissions to production rate.

The emissions estimates presented in this section are for emissions associated with normal operating conditions and do not account for variations in emissions associated with process start up and upset or control equipment malfunction and bypass. Insufficient information was available to determine the impact of these conditions on annual cadmium emissions; however, such impact would likely result in higher annual cadmium emissions rates than presented in this section.

Detailed information on annual operating times was generally lacking; in its absence, 24 hours per day, 360 days per year operating time was assumed. Moreover, many of the smelters employ Supplementary Control Systems (SCS), whereby emissions are reduced through production curtailment when ambient air quality monitoring data and meterology information indicate the possibility of violation of the National Ambient Air Quality Standard for sulfur dioxide. Insufficient information was available to determine the impact of SCS's on annual operating times and thus on annual cadmium emissions; however, such impact would generally result in annual cadmium emission rates lower than the estimates presented in this section.

4.3.1 Primary Zinc Smelters

4.3.1.1 Process Description Primary zinc smelters process zinc ore concentrates to produce metallic zinc or zinc oxide. The zinc ore is typically concentrated at the mine site and transported to the smelters for further processing. The concentrates contain 50 to 60 percent zinc, primarily as the sulfide,[1] with cadmium concentrations ranging from 0.13 to 0.80 percent.[1,2] For the purpose of this study the primary zinc industry is considered in three process categories: electrolytic zinc production, pyrometallurgical zinc production, and the direct pyrometallurgical production of zinc oxide.

The most common process is electrolytic recovery; five of the seven domestic smelters employ this process. In electrolytic recovery, the zinc sulfide concentrates are roasted to remove most of the sulfur and to form an impure oxide called calcine. The calcine is leached with sulfuric acid to form a zinc sulfate solution. The solution is purified through a series of steps in which impurities are precipitated from the solution and removed by filtration. The purified solution is then electrolyzed to obtain zinc metal at the cathode.[3]

Roasting is the only major thermal process employed in the electroytic processing of zinc ore concentrations. In roasting, only a small percentage of the cadmium in the charge material is volatilized. In addition, all of the smelters vent the off-gases from the roaster to sulfuric acid plants, the tail gases of which contain negligible amounts of particulate matter.[1] Thus, the electrolytic production of zinc has been assumed to result in negligible airborne cadmium emissions, and is not addressed further in this section.

Only one plant, St. Joe Minerals Corporation, produces metallic zinc pyrometallurgically. This company resumed operations at approximately 25 percent of its previous production capacity in early 1981, after having been inoperative since 1979.[4] Another pyrometallurgical zinc smelter, New Jersey Zinc Company, discontinued the production of zinc from concentrates in the latter part of 1980.[5]

The pyrometallurgical production of zinc, as practiced by the St. Joe smelter, consists of three major processes: roasting, sintering the roasted ore, and reducing the sinter material to metallic zinc. As in the electrolytic method the ore concentrate is roasted to remove most of the sulfur. The roasted ore is then mixed with sand, coke, returned sinter fines and other recycled material, and pelletized. The pelletized material is then roasted in downdraft sinter machines. The resultant sinter is crushed and screened. The sinter fines are recirculated to the sinter mix.

The screened sinter, coke and recycled smelter materials are heated in a rotary preheater and charged into an electrothermic furnace. Electricity is introduced through graphite electrodes to develop the heat necessary for smelting. At the operating temperature of the furnace, the zinc oxide is reduced by the coke to form metallic zinc as a vapor. The vapor is then condensed to form molten zinc. Furnace residue is discharged and treated for recovery of coke and zinc.[2]

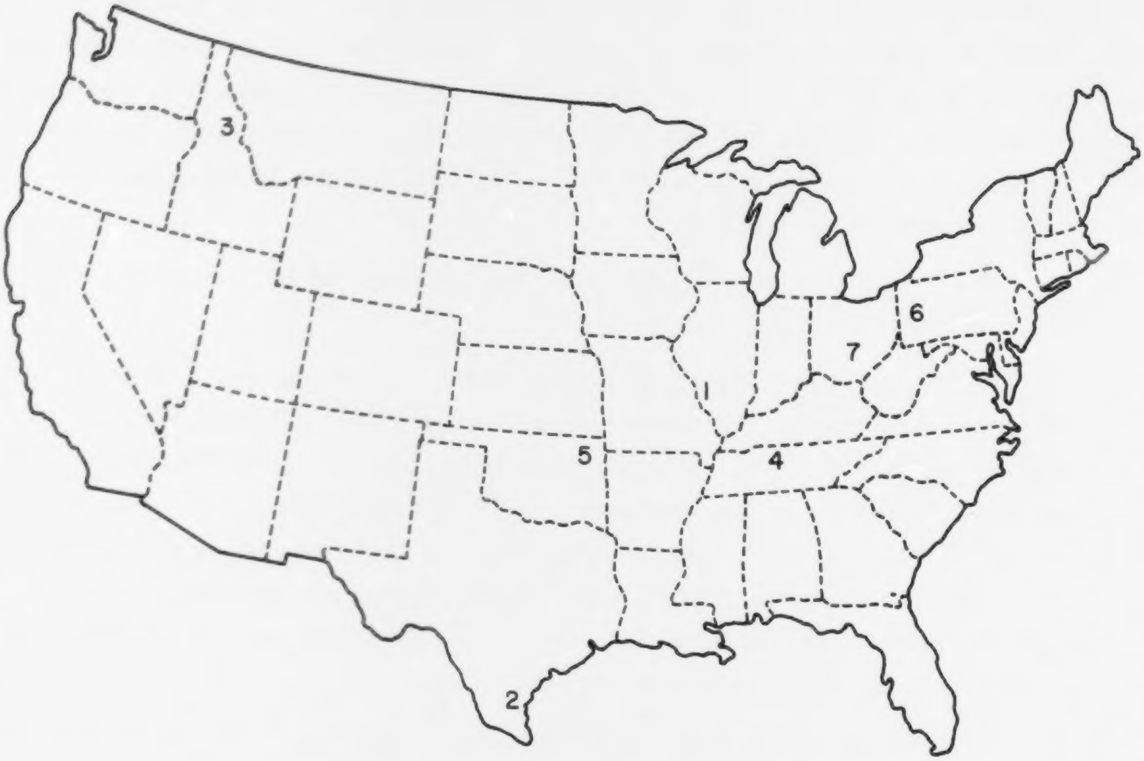
Only one plant, ASARCO-Columbus, directly produces zinc oxide pyrometallurgically from zinc concentrates. At this smelter, the ore concentrates are roasted. The resultant zinc calcine is then mixed with coke breeze and densified in a rotary kiln. The densified calcines are mixed with coke and recycle material and pelletized. The pelletized material is charged to Wetherill furnaces, where the zinc calcine is reduced to zinc vapor. The vaporized zinc is then ducted to a combustion chamber where air is admitted and the zinc vapor oxidized to zinc oxide. The zinc oxide is collected by a baghouse and is refined further by repeating the reduction-oxidation process.[6]

4.3.1.2 Geographical Location The locations of the seven domestic zinc smelters are given in Figure 4.3.1-1.

4.3.1.3 Control Techniques The control techniques for process emissions employed by the two operating pyrometallurgical zinc smelters are listed in Table 4.3.1-1. Both smelters treat the off gases from their roasters in sulfuric acid plants for sulfur dioxide removal. St. Joe controls emissions from the sintering operations with a baghouse, while off-gases from the electrothermic furnaces are vented to venturi scrubbers. The ASARCO-Columbus smelter vents emissions from all point sources to baghouses, which serve to collect the product zinc oxide.

Fugitive emissions from ore concentrate unloading, handling and storage are controlled at the St. Joe smelter by enclosure. This smelter also controls fugitive emissions from sinter preparation and recovery systems and furnace feed and residue circuits by enclosure or hooding of emission points with subsequent ventilation to baghouses. Fugitive emission controls of the ASARCO-Columbus smelter have not been determined.

4.3.1.4 Emissions Estimates Table 4.3.1-1 presents emissions estimates for the two operating pyrometallurgical zinc plants. The annual cadmium emissions from these plants are estimated to be 4.2 Mg (4.6 T). Airborne cadmium emissions from the roasters have been assumed to be negligible as discussed previously. Cadmium emissions from electrothermic furnaces and fugitive emission control at the St. Joe smelter are negligible relative to emissions from the sintering operations and, thus, have not been listed.



	Company	Location	Type
1)	AMAX, Inc.	Sauget, IL	Electrolytic
2)	ASARCO, Inc.	Corpus Christi, TX	Electrolytic
3)	The Bunker Hill Co.	Kellogg, ID	Electrolytic
4)	Jersey-Miniere Zinc. Co.	Clarksville, TN	Electrolytic
5)	National Zinc Co.	Bartlesville, OK	Electrolytic
6)	St. Joe Minerals Corp.	Monaca, PA	Pyrometallurgic
7)	ASARCO, Inc.	Columbus, OH	Pyrometallurgic (ZnO only)

Figure 4.3.1-1 Locations of primary zinc smelters.

TABLE 4.3.1-1 PRIMARY PYROMETALLURGICAL ZINC SMELTERS[*]

Smelter	Capacity Mg/yr (tpy)	Process	Process rate Mg/hr (t/hr)	Control technique	Efficiency %	Particulate emissions		Cadmium emissions		Compliance status
						kg/hr (#/hr)	Mg/yr (tpy)	kg/hr (#/hr)	Mg/yr (tpy)	
St. Joe Minerals Corp.[a] Monaca, PA	45,400 (50,000)	Roasters		Acid plants (2 in series)						SIP - In compliance
		Sinter plant		Baghouse	99	5.0 (11)	44 (48)	0.45 (0.99)	3.9 (4.3)	
		Electrothermic furnaces		Venturi scrubber						
		Total							3.9 (4.3)	
ASARCO, Inc.[b] Columbus, OH	20,000 (22,000)	Roaster	7.7 (8.5)	Acid plant						SIP - In compliance
		Densifying kilns	6.1 (6.7)	Baghouse	99.9	0.36 (0.8)	1.7 (1.9)	0.045 (0.10)	0.23 (0.25)	
		Wetherill ZnO furnaces	2.9 (3.2)	Baghouse	99.9	2.2 (4.9)	18.2 (20.1)	0.01 (0.02)	0.08 (0.09)	
		ZnO Rotary	3.6 (4.0)	Baghouse	99.9	0.01 (0.02)	0.73 (0.8)	--	--	
		Total							0.31 (0.34)	
INDUSTRY TOTAL									4.2 (4.6)	

[*] This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

Footnotes for Table 4.3.1-1

a) Information on current operations of St. Joe Minerals Corp. was obtained from a plant trip to this smelter and is summarized in reference 2. Particulate emissions have been estimated from the particulate grain loading determined by a 1979 stack test[11] and the design capacity volumetric flow rate of the sinter plant baghouse.

b) Information on ASARCO-Columbus was obtained from a 1980 air pollution emission report.[6] This report included process weight rates, equipment utilization rates, control efficiencies and estimated particulate emissions. There are no data available on cadmium emissions from zinc oxide production. To estimate cadmium emissions, cadmium to particulate ratios calculated from stack test data for a pyrometallurgical smelter[1] were applied to particulate emission estimates. To do so equivalence was assumed between densifying and sintering and between reducing in retort furnaces and reducing and subsequent oxidation in Wetherill furnaces, and the following ratios applied:

Process	Cd/PM
Sintering	0.13
Reducing	0.0046

4.3.1.5 Compliance Status*

National Ambient Air Quality Standard for Particulate Matter:

Both of the primary zinc smelters listed in Table 4.3.1-1 are in compliance with SIP limitations on particulate emissions.

National Ambient Air Quality Standard for Lead:

Pennsylvania is still developing their lead SIP and will probably submit it within the next six months.[7] It is expected that the St. Joe smelter will be in compliance.[4] Ohio has completed the development of their SIP, but has yet to submit it to the EPA regional office.[8] It is expected that the ASARCO-Columbus smelter will be in compliance.[9]

New Source Performance Standard:

An NSPS has been promulgated for zinc smelters (40 CFR 60.170) which limits particulate emissions from roasters and sinter machines; however, this standard does not apply to either of the smelters listed in Table 4.3.1-1

4.3.1.6 Comparison of National Emission Estimates with Other Studies

Over the past several years, a number of studies have estimated annual cadmium emissions for the primary zinc industry by material balance or application of emission factors. For example, Energy and Environmental Analysis estimated 480 Mg (529 T); EPA estimated 584 Mg (644 T); Sargent and Metz estimated 92 Mg (102 T); GCA estimated 454 Mg (500 T); and Mitre estimated 561 Mg (619 T).[10] This study derived an estimate of annual cadmium emissions of 4.2 Mg (4.6 T) from site-specific data on emissions, control techniques and efficiencies of these smelters. This estimate is considerably lower than previous estimates because of the reduction in emissions associated with the reduction in pyrometalluirigical processing. All but two of the primary zinc smelters have converted from pyrometallurgical to electrolytic processing. In addition, the two remaining pyrometallurgical smelters have recently reduced production, with New Jersey Zinc ceasing ore processing operations altogether and St. Joe reducing production to one-fourth of its capacity.

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

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4.3.2 Primary Lead Smelters

4.3.2.1 Process Description. Lead is produced at primary lead smelters from lead ore concentrates. The concentrates, containing 50 to 75 percent lead as lead sulfide, are normally produced at the mine site from ores containing three to eight percent lead.[1] The production of metallic lead from these concentrates involves three basic processes: sintering, blast furnace reduction, and refining.

In the sintering process, the ore concentrates are blended with recycled sinter, flue dusts, sand and other inert materials, pelletized, and roasted in updraft sinter machines. During the roasting process the lead sulfide in the concentrates is oxidized to lead oxide and sulfur dioxide. Simultaneously, the charge material is agglomerated to form a dense, permeable material called sinter. The sinter is crushed and screened for the removal of fines, which are recycle[illegible]

The screened sinter is then mixed with coke and fluxing materials, and charged into a blast furnace. At the operating temperature of the blast furnace, the coke reduces most of the metallic oxides to yield a molten mass of metal, which can separate into as many as four layers, depending on the composition of the charge. Some of the metallic impurities interact with the flux to form a slag, which typically contains high concentrations of zinc. Copper, if present in lead ores, reacts with residual sulfur to form a matte that separates into a layer beneath the slag. If the charge is high in arsenic and/or antimony, a speiss layer will form under the matte, containing arsenides and antinomides of iron and other metals. The bottom layer of lead bullion is 94 to 98 percent lead. Upon completion of the process, the slag is discharged to a fuming furnace to recover the zinc in the slag as zinc oxide. Matte and speiss are sent to a copper smelter for recovery of copper.[1]

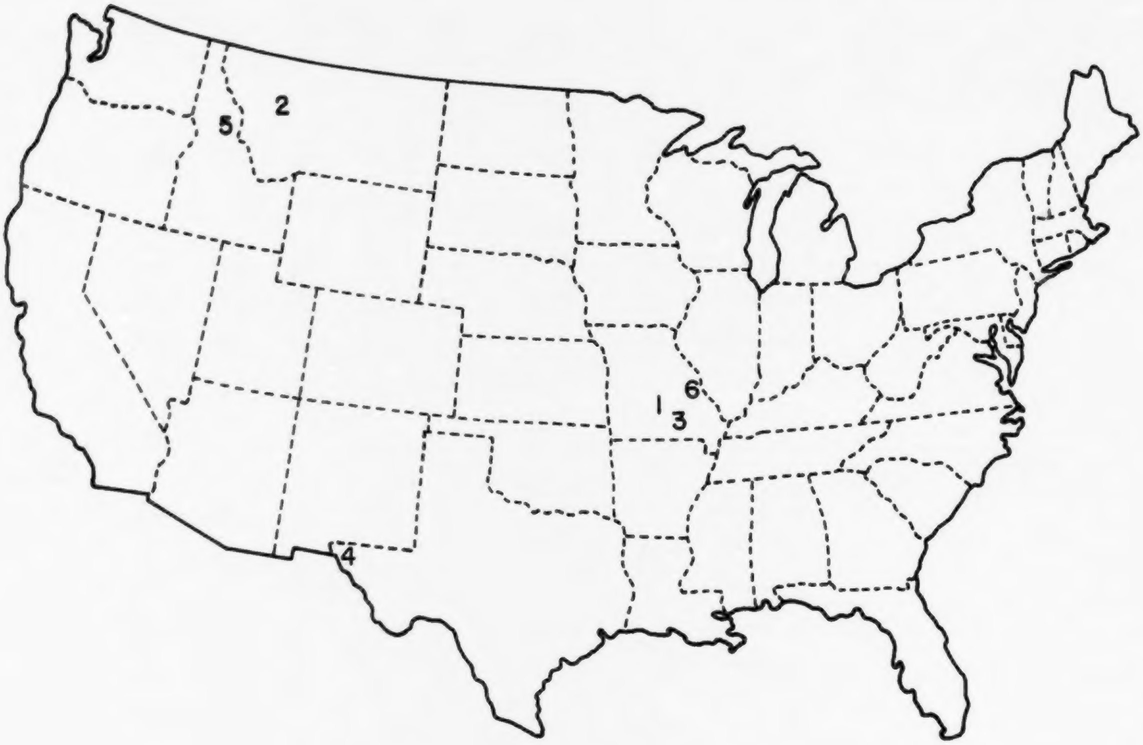
The lead bullion is then refined to eliminate remaining impurities. In the refining process, the bullion is transferred to a series of drossing kettles, where impurities are selectively removed as drosses from the lead. The drosses are treated further in a reverberatory or retort furnace for the collection of lead and the concentration of other metal values.[2]

4.3.2.2 Geographical Location There are currently six primary lead smelters in operation in the United States. The locations of these smelters are listed in Figure 4.3.2-1.

4.3.2.3 Emission Control Techniques As shown in Table 4.3.2-1, baghouses are used extensively for the control of particulate matter in the off gases from sinter machines, blast furnaces and dross furnaces. In many cases, the blast furnace and dross furnace are served by the same baghouse. At four of the six smelters, the sintering operations produce both a strong and a weak sulfur dioxide stream. The strong stream is treated in a sulfuric acid plant, while the weak stream is vented to a baghouse. Of the other two smelters, one recirculates the off gases of the blast furnace to attain a single stream with a sufficient concentration of sulfur dioxide to be treated by an acid plant; the other smelter vents all of the off gases from the sinter machine to a baghouse.

Major sources of fugitive emissions include: the handling, treating and charging of recovered sinter into the sinter machine; the handling and transfer of lead ore concentrate, zinc fuming furnace vents, blast furnace and dross furnace leakage and tapping operations. Fugitive emissions from sinter preparation and recovery systems have been controlled by hooding or enclosure of emission points and exhausting captured emissions to a control device, and by evacuation of the emissions from the sinter building to a control device. Fugitive emissions from the storage, handling and transfer of concentrate have been controlled by wet suppression or enclosure. Fugitive emissions from blast furnaces have been controlled at some smelters by enclosure of the source or by the use of fixed or movable hoods with subsequent venting to a control device.[3]

4.3.2.4 Emissions Table 4.3.2-1 presents emissions estimates for the six primary lead smelters in the United States. The annual cadmium emissions from these smelters are estimated to be 74-97 Mg (82-107 tons). Controlled point sources account for 41 Mg (45 tons), while 33-56 Mg (37-62 tons) are from fugitive sources. Annual emissions from Bunker Hill account for the majority of the emissions from the primary lead industry, with point sources emitting 30 Mg/yr (33 T/yr) and fugitive sources contributing 17 Mg/yr (19 T/yr).



Company	Location
1) AMAX-Homestake Lead Tollers	Boss, MO
2) ASARCO, Inc.	East Helena, MT
3) ASARCO, Inc.	Glover, MO
4) ASARCO, Inc.	El Paso, TX
5) The Bunker Hill Co.	Kellogg, ID
6) St. Joe Minerals Corp.	Herculaneum, MO

Figure 4.3.2-1 Locations of primary lead smelters.

TABLE 4.3.2-1 PRIMARY LEAD SMELTERS*

Smelter	Capacity Mg/yr (tpy)	Process[a]	Process rate Mg/hr (t/hr)	Control technique	Efficiency %	Particulate emissions kg/hr (#/hr)	Particulate emissions Mg/yr (tpy)	Cadmium emissions kg/hr (#/hr)	Cadmium emissions Mg/yr (tpy)	Compliance status
The Bunker Hill Co.[b] Kellogg, ID	118,000 (130,000)	Sinter machine -	75 (83)							SIP - Out of compliance
		Strong SO_2 stream		Acid plant	--					
		Weak SO_2 stream		Baghouse	--					
		Blast furnace	44 (49)	Baghouse	--	50 (110)	430 (470)	2.8 (6.1)	23 (26)	
		Refining[c]	44 (49)							
		Electric furnace	--	Baghouse	--					
		Dross reverberatory furnace	10 (11)	Baghouse	--	16 (35)	140 (150)	0.73 (1.6)	6.2 (6.9)	
		Zinc fuming furnace	29 (32)	Baghouse	--	11 (24)	95 (105)	0.02 (0.04)	0.15 (0.17)	
		Feed preparation[d]	73 (81)		--	7.3 (16)	63 (70)	0.03 (0.07)	0.27 (0.30)	
		Fugitives[e]				410 (900)	3500 (3900)	2.0 (4.4)	17 (19)	
		Total							47 (52)	
ASARCO, Inc.[f] East Helena, MT	109,000 (120,000)	Sinter machine -	29 (32)							SIP - In compliance
		Strong SO_2 stream		Acid plant						
		Weak SO_2 stream		Baghouse	99	30 (67)	262 (289)	0.080 (0.067)	0.26 (0.29)	
		Blast furnaces (1/2)	29 (32)	Baghouse	99	10 (22)	86 (95)	0.32 (0.70)	2.7 (3.0)	
		Dross reverberatory furnace	6.2 (6.8)							
		Zinc fuming furnace	25 (28)	Baghouse	99	7.7 (17)	66 (73)	0.010 (0.022)	0.085 (0.094)	
		Fugitives[g]				8.6 (19)	74 (82)	0.086 (0.19)	0.74 (0.82)	
		Total							3.8 (4.2)	
AMAX - Homestake Lead Tollers[h] Boss, MO	127,000 (140,000)	Sinter machine -	31 (34)							SIP, In compliance
		Strong SO_2 stream		Acid plant						
		Weak SO_2 stream								
		Blast furnace	28 (31)	Baghouse	99	79 (87)	284 (360)	0.58 (0.64)	2.4 (2.7)	
		Dross retort furnace	6.2 (6.8)							
		Sinter preparation & return system[i]		Scrubbers (9)	98				0.82 (0.87)	
		Fugitives[j]							4.7 - 24 (5.2 - 27)	
		Total							7.9 - 28 (8.8 - 31)	
ASARCO, Inc.[k] Glover, MO	100,000 (110,000)	Sinter machine	68 (75)	Baghouse	99	5.0 (11)	43 (48)	0.005 (0.011)	0.05 (0.05)	SIP - In compliance
		Blast furnace	46 (51)	Baghouse	99	1.7 (3.7)	15 (16)	0.05 (0.11)	0.45 (0.50)	
		Drossing kettles								
		Sinter plant ventilation[l]	68 (75)	Baghouse and scrubber	99	8.6 (19)	75 (83)	0.026 (0.057)	0.23 (0.25)	
		Fugitives[g]							0.18 (0.20)	
		Total							0.9 (1.0)	

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CONTINUED

TABLE 4.3.2-1 * (continued)

Smelter	Capacity Mg/yr (tpy)	Process[a]	Process rate Mg/hr (t/hr)	Control technique	Efficiency %	Particulate emissions		Cadmium emissions		Compliance status
						kg/hr (#/hr)	Mg/yr (tpy)	kg/hr (#/hr)	Mg/yr (tpy)	
ASARCO, Inc.[m] El Paso, TX	109,000 (120,000)	Sinter machine	29 (32)	Acid plant	--					SIP - In compliance NSPS - Out of compliance
		Blast furnace		Baghouse	--				2.7 (3.0)	
		Dross reverberatory furnace								
		Drossing kettles								
		Zinc fuming furnace		Baghouse	--				0.18[n] (0.20)	
		Deleading kilns		Baghouse	--					
		Sinter plant ventilation[o]		Baghouse	--	20 (45)	172 (190)	0.08 (0.17)	0.67 (0.74)	
		Fugitives[p]							0.74 (0.82)	
		Total							4.3 (4.7)	
St. Joe Lead Corp.[q] Herculaneum, MO	204,000 (225,000)	Sinter machine -	77 (85)							SIP - In compliance
		Strong SO_2 stream		Acid plant	99					
		Weak SO_2 stream		Baghouse	99				6.2 (6.8)	
		Blast furnaces (2/3)	77 (85)							
		Dross reverberatory furnace	4.5 (5)							
		Sinter preparation & return system[r]		Scrubbers (5)	98				1.6 (1.8)	
		Fugitives[j]							2.1 - 4.8 (2.3 - 5.3)	
		Total							9.8 - 13 (11 - 14)	
INDUSTRY TOTAL									74 - 97 (82 - 107)	

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Footnotes for Table 4.3.2-1

a) Capacity data from reference 28.

b) Information on Bunker Hill's point source emissions and associated process parameters was derived from an incomplete copy of a summary of the results of stack tests conducted at the smelter in 1974.[9] Listed particulate emissions were determined from front-half catch; cadmium emissions were determined from the total catch. Sources constituting negligible sources of cadmium emissions (i.e. slag granulators) were not included. Process information for the zinc fuming furnace was obtained from reference 11.

c) The process emission sources listed under refining are those which were measured by the emission test on the smelter main stack; they do not represent a comprehensive listing of processes associated with refining.

d) This category includes emissions from: pelletizing dryer, ore preparation plant rodmill and baghouse, and sinter tank return.

e) The fugitive emission estimate is based on the result of emissions tests conducted at this smelter in 1974, reported in reference 10. Particulate concentrations were measured using a portable dust sampler and high volume samplers. These concentrations were used in conjunction with volumetric flow data to estimate fugitive emission rates. For large areas where volumetric flow measurements were not possible, fugitive emission rates were estimated based on observed meteorological conditions. It was estimated that approximately 80% of the plant's fugitive dust emissions were measured and that the emission rates based on these measurements are within ±50% of the actual values.

f) All information about ASARCO-East Helena was derived from references 12-15. Point source emission estimates were taken from a summary of the results of stack tests conducted at the plant in September of 1979.[12] Particulate and cadmium emission rates were determined from total catch.

g) Fugitive emissions were calculated from data tabulated in reference 15. This study estimated fugitive emission rates from high volume sampler measurements for the ASARCO smelters in East Helena and Glover. These measurements were not comprehensive; however, for emission sources not included, emissions were not visually evident. Thus, the figures may be taken to be approximately representative of fugitive emissions from these smelters.

h) Information on the AMAX smelter operations has been drawn from references 17-22. Cadmium emissions from the smelter were estimated by applying a cadmium/particulate ratio of 7.4×10^{-3} derived from a 1973 stack test on the smelter's rate from a 1977 test.[19] Process weight rates and equipment utilization times were determined from AMAX's response to the Missouri emissions inventory questionnaire.[18] Annual operating times of 8007 and 8424 hrs/yr were used for the sinter machine and blast furnace respectively.

i) The cadmium emissions estimate for this source was determined from the application of a cadmium/particulate ratio for fugitive emissions from the sinter transfer area at the Bunker Hill smelter to estimated particulate emissions. Particulate emissions were estimated using stack test results that were available for four of the nine scrubber outlets.[19] Equivalence between tested and untested emission points was assumed in the same manner employed in the Missouri Lead SIP.[8]

j) Fugitive emissions from AMAX and St. Joe were estimated using lead emission estimates from the Missouri SIP[8] and cadmium to lead ratios for the relevant process sources from fugitive emission tests at ASARCO-Glover, ASARCO, East Helena and Bunker Hill.[10-15]

k) Information on ASARCO-Glover operations has been drawn from references 8, 16, 23-25. Cadmium emissions have been estimated by applying cadmium to particulate ratios from ASARCO-East Helena to particulate emission rates from 1980 stack tests.[24,25] It was assumed that the cadmium concentrations in the weak gas and total gas streams from sinter machines are the same.

l) Cadmium emissions from the ASARCO-Glover sinter plant ventilation system were estimated by applying a cadmium/particulate ratio of 3.0×10^{-3} for fugitive emissions from the plants sinter building[15] to particulate emission test results.[24,25]

m) The El Paso smelter has been modified during the past few years. There are no emissions data available for the current operations of the blast furnace. Thus, cadmium emissions were estimated by the extrapolation of ASARCO-East Helena data.

n) The joint emissions from the zinc fuming furnace and deleading kilns were approximated by doubling the extrapolated emissions estimate for zinc fuming furnace emissions.

o) Cadmium emissions from the ASARCO-El Paso sinter plant ventilation system were estimated by applying a cadmium to particulate ratio of 3.8×10^{-3} for ASARCO-East Helena sinter plant fugitive emissions[15] to particulate emission test results[26] for the El Paso plant.

p) Fugitive emissions for ASARCO-El Paso were estimated by assuming equivalence between this plant and the East Helena plant and extrapolating the emission rate from East Helena.

q) Information on St. Joe's operation was taken from references 8, 16, 27. Emissions from this smelter have been estimated by the extrapolation of ASARCO-East Helena data.

r) Cadmium emissions from the five scrubbers controlling the sinter preparation and return system have been estimated by applying a cadmium/lead ratio for the sinter transfer area at Bunker Hill[10] to the lead emissions estimate listed in the Missouri Lead SIP.[8]

Due to a lack of emissions data, emissions from the refining process generally have not been estimated. It has been assumed that cadmium emissions from refining are negligible relative to the listed process sources, because the operating temperatures of the process equipment employed in refining would not result in any appreciable volatilization of the cadmium remaining in the lead bullion.[1]

Similarly, cadmium emissions from sulfuric acid plants have not been estimated. Stack test results for the acid plant at the ASARCO-El Paso smelter, which is representative of acid plants used in the industry, show a low particulate emission rate.[4] Thus cadmium emissions from acid plants can be assumed to be negligible and therefore, emissions from acid plants have not been included in the estimates of Table 4.3.2-1.

Cadmium emissions data for fugitive emissions were available for Bunker Hill, ASARCO-Glover and ASARCO-East Helena. For AMAX and St. Joe, fugitive emissions were determined using estimates of lead emissions from the Missouri Lead SIP and cadmium to lead ratios for associated process sources from fugitive emission tests at ASARCO-Glover, ASARCO-East Helena and Bunker Hill, as appropriate. Where more than one ratio was available an upper and lower estimate was generated; this resulted in a range of estimates.

4.3.2.5 Compliance Status *

National Ambient Quality Standard for Particulate Matter:

With the exception of the Bunker Hill smelter, all of the primary lead smelters are in compliance with SIP limitations on particulate emissions.

National Ambient Air Quality Standard for Lead:

Violations of the NAAQS for lead have been monitored at all of the primary lead smelters except the ASARCO-Glover smelter. The current status of the development of state implementation plans for the lead standard in the states where these smelters are located is as follows: Missouri's plan has

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been approved;[5] Texas is revising its plan with submittal expected in 1981; Montana is developing a lead SIP for the East Helena region with submittal expected in 1982;[6] the implementation plan for Idaho is still in the development stage. The completion date of Idaho's plan is uncertain at this time since the State's air pollution control program was recently eliminated by the State legislature.[7] Missouri's SIP addresses emissions from three of the primary lead smelters: AMAX, ASARCO-Glover and St. Joe Lead. As described in the draft plan, the overall reduction (from 1979 levels) in lead emissions from these three smelters is 47 percent.[8]

New Source Performance Standard:*

A New Source Performance Standard for primary lead smelters has been promulgated (40 CFR 60.180) which limits particulate emissions from sinter machines, blast furnaces, and dross reverberatory furnaces to (50 milligrams per normal cubic meter (0.022 grains per dry standard cubic foot). The particulate emissions from the sinter plant ventilation baghouse at ASARCO-El Paso exceed this limitation.

4.3.2.6 Comparison of National Emission Estimates with Other Studies

Previous studies have estimated annual cadmium emissions for the primary lead smelters by material balance or the application of emission factors. For example, Energy and Environmental Analysis estimated 1.8 Mg (2 T); GCA estimated 50 Mg (65 T); EPA estimated 148 Mg (163 T); MITRE estimated 50 Mg (55 T); and Davis and Oak Ridge National Laboratory both estimated 952 Mg (1050 T).[29]

This study derived an estimate of annual cadmium emissions of 74-97 Mg (82-107 T) through a site-specific assessment, in which cadmium emissions data for point and fugitive emission sources were obtained for three of six smelters. This site-specific assessment indicated considerable variation in cadmium emissions among the smelters. This variation could account for the broad range in estimates made by the less detailed studies conducted previously.

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

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4.3.3 Primary Copper Smelters

4.3.3.1 Process Description

Copper is produced at primary copper smelters from copper ore concentrates. The concentrates, containing 20 to 30 percent copper as copper sulfide, are normally produced at the mine site from ores containing less than one percent copper.[1] The production of metallic copper from these concentrates involves four basic operations: roasting, smelting, converting and refining.

The copper concentrates may be roasted to eliminate a portion of the sulfur, to remove volatile impurities such as arsenic, and to preheat the material for charging into the smelting furnace. Approximately half of the primary smelters roast concentrates prior to smelting; the other half smelt the concentrates directly.[2]

In the smelting operation, roasted or raw concentrates are melted in a smelting furnace with limestone and silicaceous flux. Copper in the charge combines with sulfur to form cuprous sulfide. Excess sulfur reacts with iron to form ferrous sulfide. The combination of these two sulfides, known as matte, separates by gravity from the slag. The slag is tapped from the furnace and discarded and the matte is withdrawn for transfer to converters.[3]

In the converting operation, the copper sulfide in the matte is oxidized to form blister copper (about 99 percent copper). Copper converting is a batch process consisting of two modes of operation. In the first, referred to as the slag blow, air is blown through the charge of molten matte and siliceous fluxes and the resultant iron-bearing slag is removed, leaving molten copper sulfate. This process proceeds in a stepwise manner until a sufficient charge of molten copper sulfate (white metal) has accumulated, when the copper blow, the second state of the converting process, begins. In the copper blow, air is blown through the metal to oxidize it to blister copper. Depending upon the copper concentration of the matte, one converter cycle lasts nine to seventeen hours, with the slag blow typically comprising 80 to 90 percent of the cycle.[4]

Eleven of the fifteen smelters fire refine the blister copper from the converters. In fire refining, air is forced into the molten blister copper bath, oxidizing impurities and some of the copper. Fluxes may be added to slag off other undesirable constituents. When the copper oxide content reaches about one percent, the slag is skimmed. After the oxidation is complete, the bath is deoxidized with green logs (poling) or reformed gas. When this process has reached the desired stage, the molten copper is poured into molds to make anodes for electrolytic refining. The furnaces employed in fire refining are typically referred to as anode furnaces.[3]

4.3.3.2 Geographical Location

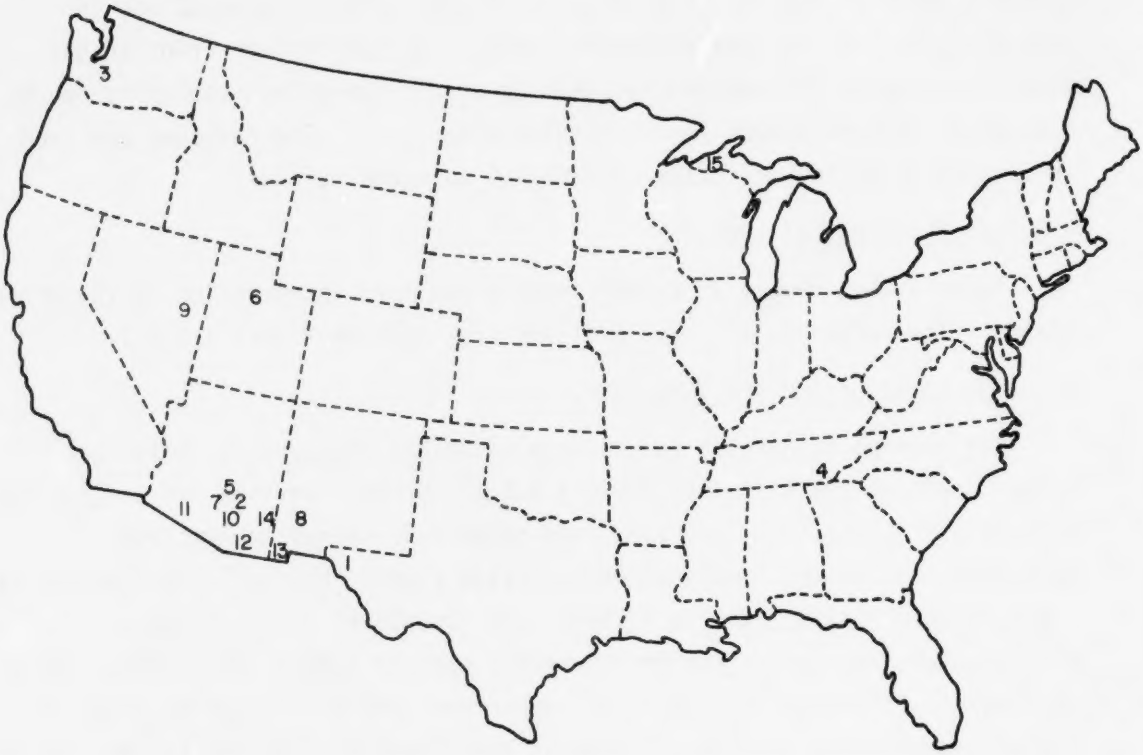
There are currently 15 primary copper smelters in operation in the United States. The locations of these smelters are given in Figure 4.3.3-1.

4.3.3.3 Emission Control Techniques

The control techniques for process emissions employed by individual copper smelters are listed in Table 4.3.3-1. Control devices for particulate emissions from roasting, smelting, and converting operations include mechanical collectors (cyclones and settling flues), hot and cold electrostatic precipitators (ESP's), fabric filters, and scrubbers. Electrostatic precipitators are by far the most commonly applied control technique. The application of venturi scrubbers at copper smelters is limited to a few smelters where they are used to augment gas stream precleaning systems and to provide additional cooling prior to acid manufacturing. Similarly, the application of baghouses is limited; only one smelter currently uses baghouses for the control of particulates in smelter off gases.[4]

Off gases from smelter equipment which produce relatively high concentrations of sulfur dioxide, inlcuding converters, fluid bed roasters, and non-reverberatory smelting furnaces, are generally treated in single or double contact acid plants for sulfur dioxide removal.[5]

Off gases from reverberatory furnaces are typically treated in hot or cold ESPs. Hot ESPs handle gases at temperatures up to 370°C (700°F). Cold ESP systems cool off gases by radiation or water sprays to about 150°C (302°F) prior to collection. The cold ESP operating temperatures result in higher control efficiencies for some trace metals.[6]



	Company	Location
1)	ASARCO, Inc.	El Paso, TX
2)	ASARCO, Inc.	Hayden, AZ
3)	ASARCO, Inc.	Tacoma, WA
4)	Cities Service Co.	Copperhill, TN
5)	Inspiration Consolidated Copper Co.	Miami, AZ
6)	Kennecott Copper Corp.	Garfield, UT
7)	Kennecott Copper Corp.	Hayden, AZ
8)	Kennecott Copper Corp.	Hurley, NM
9)	Kennecott Copper Corp.	McGill, NV
10)	Magma Copper Co.	San Manuel, AZ
11)	Phelps Dodge Copper Corp.	Ajo, AZ
12)	Phelps Dodge Copper Corp.	Douglas, AZ
13)	Phelps Dodge Copper Corp.	Hildago, NM
14)	Phelps Dodge Copper Corp.	Morenci, AZ
15)	Copper Range Co.	White Pine, MI

Figure 4.3.3-1. Locations of primary copper smelters

TABLE 4.3.3-1 PRIMARY COPPER SMELTERS*

Smelter	Capacity[a] Mg/yr (tpy)	Process[b]	Process rate Mg/hr (t/hr)	Control technique	Efficiency %	Particulate emissions		Cadmium emissions		Compliance status
						kg/hr (#/hr)	Mg/yr (tpy)	kg/hr (#/hr)	Mg/yr (tpy)	
Magma Copper Co.[c] San Manuel, AZ	181,400 (200,000)	Reverberatory furnaces (2/3)	72 (159)	ESP	--	808 (1780)	6970 (7690)	0.082 (0.180)	0.72 (0.79)	SIP, In violation
		Converters	74 (163)	SCAP (2 in parallel)	--	5.72 (12.6)	49 (54)	0.001 (0.003)	0.009 (0.01)	
		Fugitives							2.8 (3.1)	
		Total							3.5 (3.9)	
Phelps Dodge Corp.[d] Morenci, AZ	160,500 (177,000)	Fluid bed roaster		SCAP	--					SIP, In violation
		Reverberatory furnaces (4/5)	64 (70)	ESP	--	545 (1200)	4700 (5180)	0.42 (0.92)	3.57 (3.94)	
		Converters (3-4/9)	94 (104)	SCAP	--	196 (432)	1700 (1870)	0.18 (0.39)	1.54 (1.70)	
		Fugitives							2.4 (2.7)	
		Total							7.5 (8.3)	
Phelps Dodge Corp.[e] Ajo, AZ	63,500 (70,000)	Reverberatory furnace	44 (48)	ESP	96.7[f]	267 (588)	2300 (2540)	0.21 (0.46)	1.8 (2.00)	SIP, In violation
		Converters (1-2/3)	27 (30)	SCAP	--					
		Fugitives							0.6 (0.7)	
		Total							2.4 (2.7)	
Phelps Dodge Corp.[g] Douglas, AZ	115,000 (127,000)	Multihearth roasters (11-13/24)	68 (75)	ESP	--	321 (708)	2780 (3060)	0.10 (0.22)	0.84 (0.93)	SIP, in violation
		Reverberatory furnaces (2/3)	77 (85)	ESP	--					
		Converters (2/5)	63 (69)	ESP	96.5[h]	102 (225)	202 (223)	0.62 (1.37)	1.24 (1.37)	
		Fugitives							1.8 (2.0)	
		Total							3.9 (4.3)	
Kennecott Copper Corp.[i] McGill, NY	43,350 (50,000)	Reverberatory furnaces (1/2)	43 (47)	ESP	19[j]	636 (1400)	4750 (5240)	0.59 (1.29)	4.39 (4.84)	SIP, In violation
		Converters (1/4)	11 (12)	Multiclones	85[k]					
		Fugitives							0.7 (0.8)	
		Total							5.1 (5.6)	

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

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TABLE 4.3.3-1 * (continued)

Smelter	Capacity[a] Mg/yr (tpy)	Process[b]	Process rate Mg/hr (t/hr)	Control technique	Effi-ciency %	Particulate emissions		Cadmium emissions		Compliance status
						kg/hr (#/hr)	Mg/yr (tpy)	kg/hr (#/hr)	Mg/yr (tpy)	
Kennecott Copper Corp.[l] Hayden, AZ	72,600 (80,000)	Fluid bed roaster	58 (64)	DCAP	98.4[m] (As)	8.2 (18)	71 (78)	0.002 (0.005)	0.02 (0.02)	SIP, In compliance
		Converters (3/3)	40 (44)							
		Reverberatory furnace	37 (41)	ESP	96[n] (Cd)	9.5 (21)	83 (91)	0.004 (0.009)	0.04 (0.04)	
		Fugitives							1.1 (1.2)	
		Total							1.2 (1.3)	
Kennecott Copper Corp.[o] Hurley, NM	72,600 (80,000)	Reverberatory furnace (1/2)	34 (37)	ESP	--	208 (458)	1800 (1980)	0.09 (0.197)	0.77 (0.85)	SIP, in compliance
		Converters (3/4)	24 (26)	DCAP	--	10 (22)	86 (95)	0.002 (0.006)	0.03 (0.03)	
		Fugitives							1.1 (1.2)	
		Total							1.9 (2.1)	
ASARCO, Inc.[p] Hayden, AZ	163,000 (180,000)	Multihearth roasters (6-10/12)	242 (267)	ESP	--	56 (124)	486 (536)	0.03 (0.067)	0.26 (0.29)	SIP, probably[q] in compliance
		Reverberatory furnaces (2/2)								
		Converters (5/5)	34 (38)	SCAP	--	22 (49)	192 (212)	0.006 (0.013)	0.05 (0.06)	
		Fugitives							3.4 (3.7)	
		Total							3.7 (4.1)	
ASARCO, Inc.[r] El Paso, TX	104,000 (115,000)	Multihearth roasters (4/4)	--	Acid plant at lead smelter	--					SIP, In compliance
		Reverberatory furnace	42 (46)	ESP	96.7	20 (43)	169 (186)	0.011 (0.023)	0.09 (0.10)	
		Converters	--	DCAP	99.3[s] (As)					
		Fugitives							0.09[t] (0.1)	
		Total							0.2 (0.2)	
Copper Range Co.[u] White Pine, MI	81,600 (90,000)	Reverberatory furnaces (2/2)	28 (31)	ESP	--			0.42 (0.92)	2.7 (3.0)	SIP, in compliance
		Converters (2/2)	42 (46)	ESP	--			0.27 (0.60)	0.47 (0.52)	
		Fugitives							1.3 (1.4)	
		Total							4.4 (4.9)	

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TABLE 4.3.3-1 * (continued)

Smelter	Capacity[a] Mg/yr (tpy)	Process[b]	Process rate Mg/hr (t/hr)	Control technique	Efficiency %	Particulate emissions		Cadmium emissions		Compliance status
						kg/hr (#/hr)	Mg/yr (tpy)	kg/hr (#/hr)	Mg/yr (tpy)	
ASARCO, Inc.[v] Tacoma, WA	90,700 (100,000)	Multihearth roasters (5-6/10)	47 (52)	Baghouse	--					SIP, in violation of capacity
		Reverberatory furnaces (1/2)	54 (59)	ESP	--		123 (136)		0.16 (0.18)	
		Converters (2/4)	24 (26)	SCAP and LSO_2 plant	--					
		Fugitives							1.4 (1.5)	
		Total							1.5 (1.7)	
Inspiration Copper Co. Inspiration, AZ	136,000 (150,000)	Electric furnace		DCAP						SIP, in compliance
		Converters (3/5)								
		Fugitives							2.1 (2.3)	
		Total							2.1 (2.3)	
Phelps Dodge Corp. Hildago, AZ	127,000 (140,000)	Flash furnace		2 DCAP and elemental S plant						SIP, in compliance
		Converters (3/3)								
		Fugitives							2.0 (2.2)	
		Total							2.0 (2.2)	
Cities Service Co. Copperhill, TN	20,000 (22,000)	Fluid bed roaster		2 parallel DCAP						SIP, in compliance
		Electric furnace								
		Converters (1/2)								
		Fugitives							0.3 (0.3)	
		Total							0.3 (0.3)	
Kennecott Copper Corp. Garfield, UT	254,000 (280,000)	Noranda continuous smelting		Acid plants						
		Fugitives							3.9 (4.3)	
		Total							3.9 (4.3)	
INDUSTRY TOTAL									43.6 (48.2)	

SCAP = Single contact acid plant
DCAP = Double contact acid plant
ESP = Electrostatic precipitator

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Footnotes for Table 4.3.3-1

a) Blister copper production capacity information is derived from reference 4. Actual production data are unavailable.

b) For each process, the number of units operating of the total number available is given in parentheses.

c) Data on particulate emissions from the reverberatory furnaces at Magma are derived from a 1980 stack test.[14] A cadmium/particulate ratio from a 1976 stack test on this same source[15] was applied because of deficiencies in the trace metal analyses conducted in the 1980 study. It should be noted that some changes were made to the reverb process and air pollution control system between the two tests: the ability to fire the reverbs with coal as well as natural gas was added, and a fourth ESP to control particulate emissions from the reverbs was put into service. Particulate and cadmium emissions from the single absorption acid plant serving the converters are from results from the 1976 study.

d) Cadmium and particulate emission estimates for Phelps Dodge-Morenci are from stack test data summarized in reference 16. During the stack test the roaster was not in operation, and one of the reverberatory furnaces was down for repairs. However, neither of the conditions is considered to be particularly abnormal nor to have a significant effect on emissions.

e) Cadmium and particulate emissions estimates for Phelps Dodge-Ajo are from stack test data summarized in reference 17.

f) Control efficiency is taken from reference 20.

g) Cadmium and particulate emissions estimates for Phelps Dodge-Douglas are from stack test data summarized in reference 18. Annual operating times are estimated at 8640 and 1980 hr/yr for the roaster/reverbs and converters respectively.

h) Control efficiency is taken from reference 8.

i) Cadmium and particulate emissions estimates for Kennecott-McGill are from stack test data summarized in reference 19.

j) Control efficiency of the reverb ESP was calculated from emissions measurements taken both when the ESP was operating and not functioning.[19]

k) Control efficiency is taken from reference 1.

l) Process weight rates and controlled particulate emissions for Kennecott-Hayden are from stack test results summarized in reference 5.

m) Control efficiency is taken from reference 3.

n) Control efficiency is taken from reference 20.

o) Particulate emission estimates for Kennecott-Hurley are taken from stack test data summarized in references 9 and 10.

p) Process weight rates and controlled particulate emissions for ASARCO-Hayden are from stack test results summarized in reference 6. This report presents the results as a range of emission rates, the highest of which is listed in Table 2.3-1. It should be noted that the test location did not meet Method 1 criteria.

q) EPA has been unable to obtain what it considers to be valid particulate matter test data from the ASARCO-Hayden smelter because of an ongoing legal dispute regarding the adequacy of existing sampling locations. However, narrative in reference 6 indicates that the smelter is probably in compliance.

r) Stack test data pertinent to ASARCO-El Paso's current operations are not available. Since mid-1979, roaster off gases that had previously been vented to the roaster/reverb ESP have been vented to the company's lead smelter acid plant.[22] The particulate emissions from the reverb were calculated from the results of a 1977 test on the ducts venting the reverb off gases to the joint roaster/reverb ESP and control efficiency calculated for the ESP from test data. This information was summarized in reference 2.

s) Control efficiency reported in reference 2.

t) ASARCO-El Paso employs a building evacuation system with a baghouse to control fugitive emissions from the converter building. Emission measurements show particulate emission rates to be 4.4 pounds per hour. The fugitive emission estimate was adjusted to account for this.

u) Process weight rates and annual process operating times for the Copper Range smelter were obtained from the state agency.[23] Operating times of 6570 and 1740 hr/yr were used for the reverbs and converters respectively. No stack tests have been conducted on this source;[24] thus, emission factors were applied to estimate actual cadmium emissions. Cadmium/particulate ratios specific to the data used for the development of the emission factors were used to determine cadmium emissions associated with compliance with limitations on particulate emissions. The resulting emissions estimates show the smelter to be in violation, which is contrary to the actual compliance status of the plant.

v) Information on process flow, control equipment and particulate emissions for ASARCO-Tacoma was obtained from references 13 and 25. Process weight rates were obtained from reference 8. Cadmium emissions were estimated by applying a cadmium to particulate ratio for main stack emissions of 1.3×10^{-3} calculated from 1974 data given in reference 8 to 1980 annual particulate emissions from the main stack. Controlled off gases from the smelter's anode furnaces and arsenic kitchen are also vented to this stack.

Fugitive particulates emitted from primary copper smelting consist basically of metallic oxides and dust. Major sources of fugitive emissions are ore concentrate unloading and handling, roaster calcine transfer operations, furnace tapping operations, and converter charging and skimming operations. Fugitive emissions from ore concentrate handling, calcine transfer, and furnace tapping have been controlled by some smelters by hooding and enclosing the fugitive emission points and exhausting the captured emissions to a control device. Control techniques that have been applied to fugitive converter operations include the use of secondary mechanical hoods and converter building evacuation.[4] Fugitive emission controls practiced by some of the smelters are listed in Table 4.3.3-2.

The majority of the copper smelters employ acid plants to control sulfur dioxide emissions. Cadmium emissions from acid plants were estimated when cadmium or particulate emissions data were available. The resulting estimates show cadmium emissions from acid plants to be essentially negligible. This is due to the extensive particulate removal systems employed prior to the sulfuric acid plant conversion tower.[6] Consequently, for those smelters for which no acid plant emissions data were available, cadmium emissions have been assumed to be negligible.

Fugitive cadmium emissions have been estimated. However,the estimates presented are of questionable validity. They have been developed from the broad extrapolation of limited emission data. Thus, these estimates cannot be taken to adequately represent the fugitive cadmium emissions from the smelters but only to give an indication of their possible magnitude. The available data on fugitive emissions and the development of the cadmium fugitive estimates are given in Appendix A.

4.3.3.4 Emissions Estimates

Table 4.3.3-1 presents emission estimates for fifteen primary copper smelters in the United States. The annual cadmium emissions from the listed sources are estimated to be 44 Mg (48 T). Controlled point sources account for 19 Mg (21 T), while 25 Mg (27 T) are estimated to be from fugitive emission emission sources. Cadmium emissions from anode furnaces (fire refining) have not been included in these smelter specific estimates due to a lack of data. However, cadmium emissions

TABLE 4.3.3-2 CURRENT PRACTICES EMPLOYED BY COPPER SMELTERS FOR THE CAPTURE AND CONTROL OF PROCESS FUGITIVES

Smelter	Calcine discharge	Matte tapping	Slag tapping	Secondary converter emissions
ASARCO-Tacoma	Captured emissions vented to roaster baghouse	Captured emissions vented uncontrolled to main stack (to be controlled by ESP)		No capture or control
ASARCO-El Paso	Captured emissions vented to roaster/reverb ESP	Captured emissions vented to baghouse and then to roaster/reverb ESP	NI	Converter building evacuation system vented through baghouse
Phelps Dodge-Ajo	NA	Captured emissions vented uncontrolled to main stack		Captured emissions vented uncontrolled to main stack
Magma	NA	Captured emissions vented uncontrolled through separate stack		No capture or control
Phelps Dodge-Douglas	Captured emissions vented to baghouse	Captured emissions vented to converter ESP		No capture or control
ASARCO-Hayden	Captured emissions vented to reverb ESP	Captured emissions vented uncontrolled to reverb stack	No capture or control	No capture or control
Phelps Dodge-Morenci	No capture or control	Captured emissions vented uncontrolled - 4/5 reverbs to separate stack; 1/5 to converter stack		Captured emissions vented uncontrolled to converter stack
Kennecott-Hayden	NA	Captured emissions from both reverbs vented uncontrolled to separate stack	Captured emissions from 1 reverb vented uncontrolled to separate stack	No capture or control
Inspiration	NA	Captured emissions vented uncontrolled to own emission points		No capture or control
Kennecott-Garfield	NA	Captured emissions controlled with spray chamber vented to main stack		
Phelps Dodge-Hildago	NA	NI	Slag is tapped directly to electric furnace	Captured emissions vented uncontrolled to dryer stack
Kennecott-McGill	NA	No capture or control		

NI = no information
NA = not applicable

from this process cannot be assumed to be negligible. Although emissions generated by fire refining are considerably less significant both in terms of volume and trace metal content than other process emissions, with the exception of ASARCO-Tacoma, none of the smelters currently capture the off gases from anode furnaces for the control of particulate emissions.[4] Recent mass balance calculations have estimated the total annual cadmium emissions from fire refining furnaces at 57 Mg (63 T) (±93%).[7] Thus, total annual cadmium emissions from primary copper smelting are estimated to be 101 Mg (111 T).

Some of the green-fed smelters employ dryers to dry the ore concentrates prior to their charging into the smelting furnaces. Typical operating temperatures of dryers of less than 150°C[3] (302°F) would not result in appreciable volatilization of cadmium. Effective control of the dust generated in these units is typically provided[1] and particulate emission rates are low as demonstrated by stack test data from Kennecott-Hurley.[9, 10] Thus, cadmium emissions from dryers have been assumed to be negligible.

4.3.3.5 Compliance Status*

National Ambient Air Quality Standard for Particulate Matter:

The majority of the primary copper smelters are in compliance with SIP limitations on particulate emissions. The exceptions include ASARCO-Tacoma where opacity limitations are being exceeded, and five smelters (Phelps Dodge's Ajo, Morenci and Douglas facilities, Magma, and Kennecott's McGill smelter) which are affected by litigation of Phelps Dodge with Section 307 of the Clean Air Act. Phelps Dodge and EPA recently signed a consent decree, whereby Phelps Dodge agreed to bring their Morenci smelter into compliance by January 1, 1985, and their Ajo facility by December 31, 1985.[11] The status of the resolution of the litigation with respect to the other smelters is unknown at this time.

National Ambient Air Quality Standard for Lead:

The State of Arizona submitted its implementation plan for lead in April of 1980. Modeling and monitoring for the seven copper smelters in the state indicated no violations of the lead NAAQS.[12] It has been assumed that the compliance status of the Arizona smelters is representative of that of the rest of the industry, and thus, that all of the copper smelters are in compliance with the lead NAAQS.

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4.3.3.6 Comparison of National Emissions Estimates with Other Studies

Previous studies have estimated the annual airborne cadmium emissions from domestic primary copper smelters by mass balance or the application of a general industrial source emission factor, resulting in a range of estimates: Energy and Environmental Analysis estimated 4.5 Mg (5 T); GCA estimated 100 Mg (110 T); EPA estimated 212 Mg (235 T); and MITRE estimated 352 Mg (388 T).[26] This study's annual cadmium emissions estimate of 101 Mg (111 T) is in general agreement with previous assessments. This estimate was derived through a site specific assessment in which extensive stack test data of cadmium and particulate emissions were available for process point sources. The annual emissions estimate also incorporates a recent mass balance estimate of the industry's emissions from fire refining and an estimate of fugitive emissions from the application of an emission factor.

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4.3.4 Primary Cadmium Production

4.3.4.1 Process Description. Cadmium is produced primarily as a by-product of zinc production. Cadmium is recovered from the following by-product materials: flue dusts from the sintering of zinc calcines, sludges from the purification of zinc electrolyte solution in the electrolytic production of zinc, recycled zinc metal containing cadmium, and flue dusts from lead-smelting. Cadmium is produced from these materials by both pyrometallurgic and electrolytic processes.[1]

Prior to electrolytic or pyrometallurgic smelting, flue dusts are typically leached with sulfuric acid. The leach solution is then treated with zinc dust to precipitate cadmium as a metallic sponge, which is filter pressed. Precipitate from the purification of zinc electrolyte is typically used directly as a raw material for cadmium production. This precipitate generally has a high cadmium concentration; in the purification of zinc electrolyte, copper and cadmium are removed from solution in stages by treating the electrolyte with zinc dust, making possible the seperation of precipitated impurities into high-copper and high-cadmium fractions.[1]

Cadmium sponge and high-cadmium precipitates are purified by electrolytic or pyrometalluric processes. In electrolytic production, the cadmium sponge or precipitate is first leached with sulfuric acid and spent electrolyte. The solution may be purified by selective precipitation of impurities and subsequent filtration. The leach solution is then electrolyzed to obtain cadmium metal at the cathode.[2] In pyrometallurgical production, dried cadmium sponge or precipitate is first mixed with coal or coke and lime and then transferred to a retort furnace where the cadmium is reduced and collected as molten metal in a condenser. Cadmium metal that is produced either pyrometallurgically or electrolytically is melted in a furnace and then cast.[1]

Although, for the most part, primary cadmium production is conducted at primary zinc smelters, it has been considered here as a seperate industrial category. This approach has not overlooked air pollution problems due to the additive emissions from both zinc and cadmium smelting, since no facility produces both zinc and cadmium pyrometallurgically.

4.3.4.2 Geographical Location. The locations of the seven primary cadmium smelters are shown in Figure 4.3.4-1. An eighth smelter, St. Joe Minerals Corporation, located in Monaca, PA, is no longer producing cadmium. With the exception of the ASARCO smelter in Denver and New Jersey Zinc Company all of these facilities also produce zinc metal. Four of these facilities produce cadmium eletrolytically, while three employ the pyrometallurgical method.

4.3.4.3 Control Techniques. Airborne emissions associated with the electrolytic process are negligible and thus, this emission source is typically uncontrolled. Furnaces used for the pyrometallurgical smelting of cadmium are equipped with baghouses. Furnaces used for the melting of cadmium metal are also typically equipped with baghouses.[1]

4.3.4.4 Emission Estimates. An estimate of annual cadmium emissions from primary cadmium production has been made by the application of an emission factor[4] to cadmium production data. Primary cadmium production is estimated at 1885 Mg/yr (2073 t/yr), assuming continued production at the 1979 levels listed in Figure 4.3.4-1. The resulting annual cadmium emissions estimate is 1.3 Mg (1.4 tons). Due to this low total industry mass emissions estimate, the smelters were not assessed on a case-by-case basis; however, dispersion modeling of two pyrometallurgical smelters was conducted (see Chapter 5).

4.3.4.5 Compliance Status.* Since a smelter-specific assessment was not conducted for this source category, the compliance status of primary cadmium production facilities was not determined.

4.3.4.6 Comparison of National Emission Estimates with Other Studies. In previous studies, annual airborne cadmium emissions from primary cadmium smelters were estimated to be 55 Mg (60 tons) by EPA, 45 Mg (50 tons) by GCA, 1.8 Mg (2.0 tons) by Energy and Environmental Analysis (EEA)[4] and 1.5 Mg (1.7 tons) by JRB.[5] This study's annual cadmium emissions estimate of 1.3 Mg (1.4 tons) was made using the same emission factor used by EEA, which reflects current control of airborne emissions. This estimate compares well with the recent emissions estimate made by JRB.

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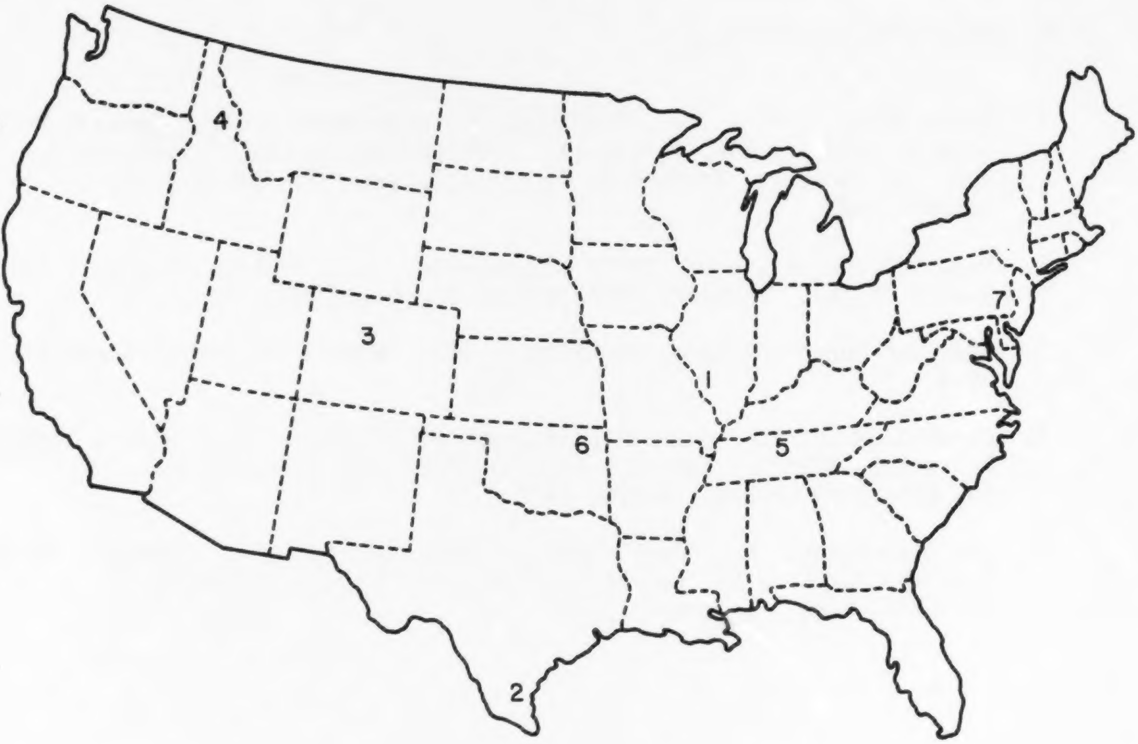
*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.



	Company	Location	Type	1979 production[3] Mg/yr	 (t/yr)
1)	AMAX, Inc.	Sauget, IL	Pyrometallurgic	390	(429)
2)	ASARCO, Inc.	Corpus Christi, TX	Electrolytic	389	(428)
3)	ASARCO, Inc.	Denver, CO	Electrolytic		
4)	The Bunker Hill Co.	Kellogg, ID	Electrolytic	270	(297)
5)	Jersey-Miniere Zinc Co.	Clarksville, TN	Electrolytic	273[a]	(300)[a]
6)	National Zinc Co.	Bartlesville, OK	Pyrometallurgic	275	(302)
7)	New Jersey Zinc Co.	Palmerton, PA	Pyrometallurgic	288	(317)

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[a] Production assumed at capacity.

Figure 4.3.4-1. Locations of primary cadmium production facilities.

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4.4 MUNICIPAL REFUSE INCINERATION

4.4.1 Introduction

As presented in Section 3, Uses of Cadmium, cadmium is found in a variety of consumer products which eventually may become part of the municipal refuse. Of the four largest uses of cadmium in consumer products, electroplating, batteries, pigments, and plastic stabilizers, only batteries are recycled for their cadmium content. Table 4.4-1 presents a breakdown of typical municipal refuse compositions as determined in a Bureau of Mines Study.[1]

TABLE 4.4-1 COMPOSITION OF TYPICAL REFUSE

Product	Percent by Weight	Product	Percent by Weight
Paper	51.7	Wood	2.6
Glass	10.5	Fabrics	1.8
Fine Glass, Grit Dirt and Ceramics	10.0	Aluminum	1.1
Ferrous Metal	7.6	Miscellaneous	0.9
Plastics	5.0	Leather and Rubber	0.7
Putrescibles	4.4	Zinc Base Metal	0.14
Corrugated Board	3.5	Copper Base Metal	0.06

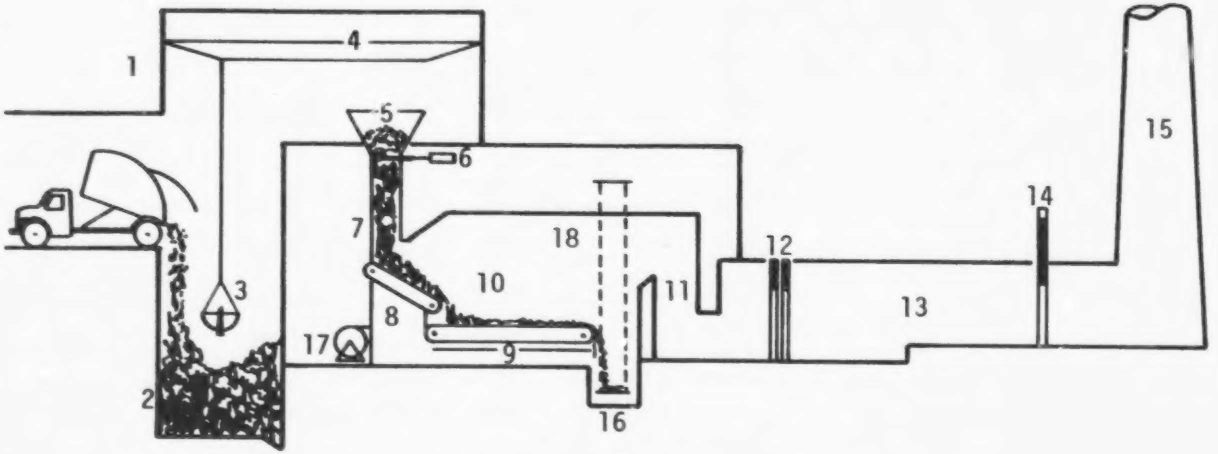
Refuse has been reported to contain cadmium in both the combustible and noncombustible fractions.[1] Some incineration facilities, especially those with heat recovery capabilities, separate out the noncombustible material before incineration. Approximately 70 percent of municipal refuse is combustible.[2] Of this 70 percent, an average of nine parts per million (ppm) by weight is cadmium and varies from two to 22 ppm.[1] The temperatures at which refuse is incinerated are generally sufficient to vaporize most of the cadmium contained in the refuse.

There are 44 municipal incinerators in the United States with capacities above 45.4 Mg per day (50 TPD).[3] There are an additional 90 units at 41 locations with capacities under 45.4 Mg per day (50 TPD).[4] This 45.4 Mg per day (50 TPD) stratification occurs as a result of the New Source Performance Standard's (NSPS) lower limit for affected facilities.[5] Municipal incinerators burning less than 45.4 Mg per day (50 TPD) are not regulated by the NSPS.

4.4.2 Process Description

A variety of conventional incinerator designs are currently being used in the United States, although almost all incorporate a multiple-chamber operation. The combustion process in a multiple-chamber incinerator proceeds in two stages: primary or solid fuel combustion in the ignition chamber (primary combustion chamber), followed by by secondary or gas-phase combustion in a separate chamber (secondary combustion chamber). In the primary chamber, the solid fuel is dried, ignited, and combusted. As the burning proceeds, the moisture and volatile components of the fuel are vaporized and partially oxidized in passing from the ignition chamber through the flame port connecting the ignition chamber with the mixing chamber. From the flame port, the volatile components of the refuse and the products of combustion flow down through the mixing chamber into which secondary air is introduced. Abrupt changes in the speed and direction of the primary combustion products produces turbulent mixing with the secondary air. Secondary burners may be necessary to provide additional heat to the mixture to complete the combustion. Figure 4.4-1 presents a conventional multiple-chamber municipal incinerator. Variations in incinerator design include rocking, circular, reciprocating, or traveling grates, manual or automatic stoking, starved air or excess air design, and waterwall or refractory wall.[6]

In most conventional incineration systems, the temperature immediately above the burning waste ranges from 1149°C to 1371°C (2100°F to 2500°F), while the temperature leaving the combustion chamber is in the range of 760°C to 871°C (1400°F to 1600°F).[7] These temperatures are at or above the boiling point for cadmium.[8] Due to the high cost of fossil fuel, some incinerators have included heat recovery capabilities in their design. There are currently 11 of these operating in the United States above a capacity of 45.4 Mg per day (50 TPD). Table 4.4-2 presents a list of operating locations, capacity, and type for municipal incinerators above 45.4 Mg per day (50 TPD).



1. INCINERATOR
2. STORAGE PIT
3. GRAP BUCKET
4. BRIDGE CRANE
5. CHARGING HOPPER
6. HOPPER GATE
7. WATER-COOLED HOPPER
8. FEEDING AND DRYING STOKER
9. BURNING STOKER
10. PRIMARY COMBUSTION CHAMBER
11. SECONDARY COMBUSTION CHAMBER
12. GAS-CLEANING CHAMBER
13. FLUE
14. DAMPER
15. STACK
16. ASH CONVEYOR
17. FORCED-DRAFT FAN
18. REFACTORY ENCLOSURES

Figure 4.4-1 Conventional multiple-chamber municipal incinerator.[9]

TABLE 4.4-2a CONVENTIONAL INCINERATORS*
(Metric units)

	Company name	Operating location	type	Control technique	Operating average Mg/day	Mg per year	Control equipment efficiency	Compliance standard status	Allowable emissions	Uncontrolled particulate emissions kg/hr	Controlled particulate emissions kg/hr	Uncontrolled cadmium emissions kg/hr	Controlled cadmium emissions kg/hr	Annual controlled particulate emissions Mg/yr	Annual controlled cadmium emissions Mg/yr	Annual uncontrolled cadmium emissions Mg/yr
UNITS WITHOUT HEAT RECOVERY																
1	Ansonia	Ansonia, CT		Low pressure scrubber	136 (3) 5 d/w (1)	35,380^c	60% (2)	SIP, In compliance, source test		85	34	.125	.050	212	.313	.783
2	Stamford	Stamford, CT	Starved air rocking grate (3)	ESP (3)	145 5½ d/w (3)	41,513^c	90% (2)			91	9	.134	.014	62	.091	.916
3	New Canaan	New Canaan, CT	Starved air reciprocating (3)	Venturi low energy	91 (3) 5 d/w	23,587^c	80% (2)	SIP, In compliance, source test		57	11	.083	.017	71	.104	.522
4	E. Hartford	E. Hartford, CT	Kiln (3)	Wet settling chamber (3)	136 (3)	35,380^c	60% (2)	SIP, In compliance, certification		85	34	.125	.050	212	.313	.783
5	Bridgeport	Bridgeport, CT	S H U T D O W N (2)													
6	SWR #1	Washington, DC	Train (3)	Multiclones 26/line (3)	1361 (2) 5 d/w (3)	353,802^c	50% Assumed	SIP, In violation, mtg. sched.		851	425	1.25	.626	2654	3.91	7.83
7	Orlando	Orlando, FL	Starved air reciprocating (3)	ESP (3)	91 (3) 5 d/w	23,587^c	90% Assumed	SIP, In compliance, inspect		57	5	.083	.008	35	.052	.522
8	Dade County	Dade County, FL	Starved air rocking (3)	ESP (3)	218 (3) 5 d/w (3)	56,608^c	90% (2)	SIP, In compliance, source test		136	14	.200	.020	84	.125	1.25
9	Waipaho	Honolulu, HI	3 stage traveling grate (3)	ESP (3)	408 (3) 5 d/w (1)	127,369^c	90% Assumed	SIP, In compliance, inspect		255	25	.376	.038	191	.281	2.82
10	E. Chicago	E. Chicago, IN	Starved air rocking grate (3)	Wet settling chamber (3)	295 (3) 5 d/w (3)	76,657^c	85% (2)			184	27	.272	.041	172	.254	1.70
11	Louisville	Louisville, KY	Starved air reciprocating (3)	Low energy scrubber (3)	771 (3) 7 d/w (3)	280,683^c	20% Design (2)			402	386	.708	.567	3367	4.96	6.21
12	Shreveport	Shreveport, LA	Water wall reciprocating (3)	Cyclone (3)	154 (3) 5 d/w (3)	40,098^c	50% Design (2)	SIP, In violation, not mtg. sched.		96	48	.142	.071	300	.444	.887
13	Baltimore	Baltimore, MD	Water wall (3)	ESP (3)	726 (3) 6 d/w (3)	226,433^c	99% Design (2)	SIP, In violation, mtg. sched.		454	5	.667	.007	34	.500	5.01
14	Fall River	Fall River, MA	Starved air reciprocating (3)	High energy scrubber and ESP (3)	544 (3) 5 d/w (3)	141,521^c	95% Assumed	SIP, In violation, mtg. sched.		340	17	.499	.025	106	.157	3.13
15	Framingham	Framingham, MA	Starved air reciprocating (3)	Baghouse (3)	181 (3) 5 d/w Assumed	47,174^c	40% (2)	SIP, In compliance, cerfication		113	68	.167	.100	424	.626	1.04
16	Bridgewater	Bridgewater, MA		Baghouse	272 (4) 5 d/w Assumed	70,760^c	40% Assumed	NSPS, In compliance, particulate source test		170	102	.251	.151	637	.943	1.56
17	St. Louis	St. Louis, MO	Starved air (3) manual stacked	Low energy scrubber (3)	363 (3) 5 d/w	94,347^c	88% (2)	SIP, In compliance, inspect		227	27	.334	.040	170	.250	2.09
18	St. Louis	St. Louis, MO	Starved air manual stacked (3)	Low energy scrubber (3)	508 (2) 5 d/w (3)	132,086^c	88% (2)	SIP, In compliance, inspect		318	38	.467	.056	238	.350	2.92
19	Red Bank	Red Bank, NJ	Starved air reciprocating (3)	Low energy scrubber	32 (3) 6 d/w (3)	9,906^c	20% Assumed	SIP, In compliance, inspect		20	16	.029	.024	119	.175	.211
20	Huntington	Huntington, NY	Starved air (3); #1, #2-manual stacking, #3-reciprocating	#1,#2-low energy scrubber, #3-ESP	272 (3) 5 d/w	70,760^c	43.3% Assumed	SIP, In compliance, certification	50 kg/hr	170	96	.251	.142	601	.888	1.57
21	Oyster Bay	Oyster Bay, NY	Starved air reciprocating (3)	Low energy scrubber (3)	907 (3) 5 d/w (3)	235,868^c	20% Assumed	SIP, In violation, not mtg. sched.	91 kg/hr	567	454	.835	.667	2830	4.17	5.22
22	Tonawanda	Tonawanda, NY	Starved air reciprocating (3)	Wet settling chamber (3)	227 (3) 5 d/w	58,967^c	72.5% Assumed	SIP, In compliance, certification	37 kg/hr	142	39	.209	.057	243	.358	1.31

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TABLE 4.4-2a * (continued)

	Company name	Operating location	type	Control technique	Operating average Mg/day	Mg per year	Control equipment efficiency	Compliance standard status	Allowable emissions	Uncontrolled particulate emissions kg/hr	Controlled particulate emissions kg/hr	Uncontrolled cadmium emissions kg/hr	Controlled cadmium emissions kg/hr	Annual controlled particulate emissions Mg/yr	Annual controlled cadmium emissions Mg/yr	Annual uncontrolled cadmium emissions Mg/yr
23	Lackawanna	Lackawanna, NY	Starved air (3) Manual stacking	Wet settling chamber (3)	907 (4) 5 d/w (3)	235,868^c	72.5% Assumed	SIP, In compliance, certification	47 kg/hr	567	57	.835	.083	354	.522	5.22
24	S. Brooklyn	New York, NY		ESP	907 (4) 5 d/w (4)	235,868^c	90% Assumed		47 kg/hr	567	57	.835	.083	354	.522	5.22
25	Green Point	New York, NY		ESP	907 (4) 5 d/w	235,868^c	90% Assumed	SIP, In violation, mtg. sched.	47 kg/hr	567	57	.835	.083	354	.522	5.22
26	Hamilton Av.	New York, NY	to be closed 1981	ESP-Assumed	907 (4) 5 d/w	235,868^c	90% Assumed	SIP, in violation, not mtg. sched.	47 kg/hr	567	57	.835	.083	354	.522	5.22
27	Lakewood	Lakewood, OH		Cyclone	150 5 d/w Assumed	30,910^c	50% Assumed	SIP, In compliance, certification		93	47	.138	.069	291	.431	.861
28	E. Central	Philadelphia, PA	Starved air traveling (3)	ESP (3)	635 (3) 7 d/w	231,151^c	90% Assumed			397	39	.585	.069	347	.511	5.11
29	N. West	Philadelphia, PA	Starved air (3) chain	ESP (3)	635 (3) 7 d/w	231,151^c	90% Assumed			397	39	.585	.059	347	.511	5.11
30	Shippensburg	Shippensburg, PA	Rotary kiln (3)	Low energy scrubber (3)	65 (3) 5 d/w Assumed	16,982^c	20% Assumed			41	33	.060	.048	203	.300	.376
31	Webber County	Webber Cty., PA	Starved air reciprocating (3)	ESP (3)	101 (3) 6 d/w	56,608^c	90% Assumed			113	11	.167	.017	84	.125	1.25
32	Newport News	Newport News, VA	Starved air reciprocating (3)	ESP (3)	272 (3) 7 d/w (3)	99,065^c	90% Assumed			170	17	.251	.025	148	.220	2.20
33	Portsmouth	Portsmouth, VA	Starved air (3) Rolling grate	Wet settling chamber (3)	318 (3) 5½ d/w	90,[illegible]^c	72.5% Assumed			198	54	.293	.080	374	.352	2.00
34	Sheboygan	Sheboygan, WI	Water wall raking (3)	Low energy scrubber (3)	136 (3) 5 d/w Assumed	35,380^c	20% (2)	SIP, In compliance, certification		85	68	.125	.100	425	.626	.783
	Total without heat recovery					3,926,022				6662	2416	12.751	3.960	16,397	24.628	86.862
UNITS WITH HEAT RECOVERY																
1	N. West	Chicago, IL	Starved air reciprocating (3)	ESP (3)	1451 (3) 365 d/y (3)	529,796^c	90% Assumed			907	91	1.34	.134	795	1.17	11.7
2	Baltimore	Baltimore, MD	Rotating kiln (3)	ESP (3)	907 (3) 7 d/w	330,215^c	90% Assumed			567	57	.835	.083	495	.730	7.30
3	Resco	Saugus, MA	Starved air traveling gate (3)	ESP (3)	1089 365 d/y	397,347^c	90% Assumed	NSPS, In compliance, particulate source test		680	68	1.00	.100	596	.879	8.79
4	Braintree	Braintree, MA		ESP-Assumed	218, 5 d/w	56,608^c	90%-Assumed			136	14	.200	.020	764	1.13	1.25
5	Betts	New York, NY		ESP-Assumed	907, 5 d/w Assumed	235,868^c	90%-Assumed	SIP, in violation, mtg. sched.	47 kg/hr	567	57	.835	.083	354	.522	5.22
6	Hempstead	Hempstead, NY	Water wall reciprocating (3)	ESP (3)	1 @ 544 1 @ 680 7 d/w (3)	445,791^c	90% Assumed	SIP, In compliance, source test		765	76	1.13	.113	669	.989	9.89
7	S. West	Brooklyn, NY	Cascading	ESP (3)	544 (3)	SHUTDOWN (5)										
8	Harrisburg	Harrisburg, PA	Starved air reciprocating (3)	ESP (3)	653 (3) 365 d/y	238,408^c	90% Assumed			408	41	.603	.060	357	.527	5.27
9	Nashville	Nashville, TN	Starved air reciprocating (3)	ESP (3)	653 (3) 365 d/y	238,408^c	90% Assumed	NSPS, In compliance, source test		408	41	.603	.060	357	.527	5.27
10	Norfolk Navy Public Works	Norfolk, VA	Starved air reciprocating (3)	ESP (3)	327 (3) 7 d/w (3)	118,077^c										
15	Waukesha	Waukesha, WI	Refratory wall (3) reciprocating	ESP (3)	100 (3) 5 d/w-Assumed	25,945^c	90% Assumed			62	6	.092	.009	39	.057	.573
	Total with .eat recovery					2,617,263				4500	451	6.638	.662	4426	6.531	55.263
	Total with and without heat recovery					6,543,285				13,162	2867	19.389	4.222	20,823	31.159	142.125

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

TABLE 4.4-2b CONVENTIONAL INCINERATORS*
(English units)

	Company name	Operating location	type	Control technique	Operating average TPD	Tons per year	Control equipment efficiency	Compliance standard status	Allowable emissions	Uncontrolled particulate emissions #/hr	Controlled particulate emissions #/hr	Uncontrolled cadmium emissions #/hr	Controlled cadmium emissions #/hr	Annual controlled particulate emissions T/yr	Annual controlled cadmium emissions T/yr	Annual uncontrolled cadmium emissions T/yr
UNITS WITHOUT HEAT RECOVERY																
1	Ansonia	Ansonia, CT		Low pressure scrubber	150 (3) 5 d/w (1)	39,000^c	60% (2)	SIP, In compliance, source test		187	75	.276	.11	234	.345	.863
2	Stamford	Stamford, CT	Starved air rocking grate (3)	ESP (3)	160 5½ d/w (3)	45,760^c	90% (2)			290	30	.295	.030	66	.10	1.01
3	New Canaan	New Canaan, CT	Starved air reciprocating (3)	Venturi low energy	100 (3) 5 d/w	26,000^c	80% (2)	SIP, In compliance, source test		125	25	.184	.037	78	.115	.575
4	E. Hartford	E. Hartford, CT	Kiln (3)	Wet settling chamber (3)	150 (3)	39,000^c	60% (2)	SIP, In compliance, certification		187	75	.276	.11	234	.345	.863
5	Bridgeport	Bridgeport, CT	SHUTDOWN (2)													
6	SWR #1	Washington, DC	Train (3)	Multiclones 26/line (3)	1500 (2) 5 d/w (3)	390,000^c	50% Assumed	SIP, In violation, mtg. sched.		1875	937	2.76	1.38	2925	4.31	8.63
7	Orlando	Orlando, FL	Starved air reciprocating (3)	ESP (3)	100 (3) 5 d/w	26,000^c	90% Assumed	SIP, In compliance, inspect		125	12	.184	.018	39	.057	.575
8	Dade County	Dade County, FL	Starved air rocking (3)	ESP (3)	240 (3) 5 d/w (3)	62,400^c	90% (2)	SIP, In compliance, source test		300	30	.442	.044	93	.138	1.38
9	Waipaho	Honolulu, HI	3 stage traveling grate (3)	ESP (3)	450 (3) 5 d/w (1)	140,400^c	90% Assumed	SIP, In compliance, inspect		562	56	.830	.083	210	.310	3.11
10	E. Chicago	E. Chicago, IN	Starved air rocking grate (3)	Wet settling chamber (3)	325 (3) 5 d/w (3)	84,500^c	85% (2)			406	60	.600	.090	190	.280	1.87
11	Louisville	Louisville, KY	Starved air reciprocating (3)	Low energy scrubber (3)	850 (3) 7 d/w (3)	309,400^c	20% Design (2)			1062	850	1.56	1.25	3712	5.47	6.85
12	Shreveport	Shreveport, LA	Water wall reciprocating (3)	Cyclone (3)	170 (3) 5 d/w (3)	44,200^c	50% Design (2)	SIP, In violation, not mtg. sched.		212	106	.313	.157	331	.489	.978
13	Baltimore	Baltimore, MD	Water wall (3)	ESP (3)	800 (3) 6 d/w (3)	249,600^c	99% Design (2)	SIP, In violation, mtg. sched.		1000	10	1.47	.015	37	0.55	5.52
14	Fall River	Fall River, MA	Starved air reciprocating (3)	High energy scrubber and ESP (3)	600 (3) 5 d/w (3)	156,000^c	95% Assumed	SIP, In violation, mtg. sched.		750	38	1.10	.055	117	.173	3.45
15	Framingham	Framingham, MA	Starved air reciprocating (3)	Baghouse (3)	200 (3) 5 d/w Assumed	52,000^c	40% (2)	SIP, In compliance, cerfication		250	150	.369	.221	468	.690	1.15
16	Bridgewater	Bridgewater, MA		Baghouse	300 (4) 5 d/w Assumed	78,000^c	40% Assumed	NSPS, In compliance, particulate source test		375	225	.553	.332	702	1.04	1.72
17	St. Louis	St. Louis, MO	Starved air (3) manual stacked	Low energy scrubber (3)	400 (3) 5 d/w	104,000^c	88% (2)	SIP, In compliance, inspect		500	60	.737	.089	187	.276	2.30
18	St. Louis	St. Louis, MO	Starved air manual stacked (3)	Low energy scrubber (3)	560 (2) 5 d/w (3)	145,600^c	88% (2)	SIP, In compliance, inspect		700	84	1.03	.124	262	.386	3.22
19	Red Bank	Red Bank, NJ	Starved air reciprocating (3)	Low energy scrubber	35 (3) 6 d/w (3)	10,920^c	20% Assumed	SIP, In compliance, inspect		43	35	.064	.352	131	.193	.241
20	Huntington	Huntington, NY	Starved air (3); #1, #2-manual stocking, #3-reciprocating	#1,#2-low energy scrubber, #3-ESP	300 (3) 5 d/w	78,000^c	43.3% Assumed	SIP, In compliance, certification	55 #/hr	375	212	.553	.313	663	.979	1.73
21	Oyster Bay	Oyster Bay, NY	Starved air reciprocating (3)	Low energy scrubber (3)	1000 (3) 5 d/w (3)	260,000^c	20% Assumed	SIP, In violation, not mtg. sched.	103 #/hr	1250	1000	1.84	1.47	3120	4.60	5.75
22	Tonawanda	Tonawanda, NY	Starved air reciprocating (3)	Wet settling chamber (3)	250 (3) 5 d/w	65,000^c	72.5% Assumed	SIP, In compliance, certification	41 #/hr	312	85	.461	.126	268	.395	1.44

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TABLE 4.4-2b * (continued)

	Company name	Operating location	type	Control technique	Operating average TPD	Tons per year	Control equipment efficiency	Compliance standard status	Allowable emissions	Uncontrolled particulate emissions #/hr	Controlled particulate emissions #/hr	Uncontrolled cadmium emissions #/hr	Controlled cadmium emissions #/hr	Annual controlled particulate emissions T/yr	Annual controlled cadmium emissions T/yr	Annual uncontrolled cadmium emissions T/yr
23	Lackawanna	Lackawanna, NY	Starved air (3) Manual stacking	Wet settling chamber (3)	1000 (4) 5 d/w (3)	260,000^{c}	72.5% Assumed	SIP, In compliance, certification	103 #/hr	1250	125	1.84	.184	390	.575	5.75
24	S. Brooklyn	New York, NY		ESP	1000 (4) 5 d/w (4)	260,000^{c}	90% Assumed		103 #/hr	1250	125	1.84	.184	390	.575	5.75
25	Green Point	New York, NY		ESP	1000 (4) 5 d/w	260,000^{c}	90% Assumed	SIP, In violation, mtg. sched.	103 #/hr	1250	125	1.84	.184	390	.575	5.75
26	Hamilton Av.	New York, NY	to be closed 1981	ESP-Assumed	1000 (4) 5 d/w	260,000^{c}	90% Assumed	SIP, in violation, not mtg. sched.	103 #/hr	1250	125	1.84	.184	390	.575	5.75
27	Lakewood	Lakewood, OH		Cyclone	165 5 d/w Assumed	42,900^{c}	50% Assumed	SIP, In compliance, certification		206	103	.304	.152	321	.475	.949
28	E. Central	Philadelphia, PA	Starved air traveling (3)	ESP (3)	700 (3) 7 d/w	254,800^{c}	90% Assumed			875	87	1.29	.129	382	.563	5.63
29	N. West	Phialdelphia, PA	Starved air (3) chain	ESP (3)	700 (3) 7 d/w	254,800^{c}	90% Assumed			875	87	1.29	.129	382	.563	5.63
30	Shippensburg	Shippensburg, PA	Rotary kiln (3)	Low energy scrubber (3)	72 (3) 5 d/w Assumed	18,720^{c}	20% Assumed			90	72	.133	.106	224	.331	.414
31	Webber County	Webber Cty., PA	Starved air reciprocating (3)	ESP (3)	290 (3) 6 d/w	62,400^{c}	90% Assumed			250	25	.369	.037	93	.138	1.38
32	Newport News	Newport News, VA	Starved air reciprocating (3)	ESP (3)	300 (3) 7 d/w (3)	109,200^{c}	90% Assumed			375	37	.553	.055	163	.242	2.42
33	Portsmouth	Portsmouth, VA	Starved air (3) Rolling grate	Wet settling chamber (3)	350 (3) 5½ d/w	100,100^{c}	72.5% Assumed			437	120	.645	.177	412	.609	2.2:
34	Sheboygan	Sheboygan, WI	Water wall raking (3)	Low energy scrubber (3)	150 (3) 5 d/w Assumed	39,000^{c}	20% (2)	SIP, In compliance, certification		187	150	.276	.221	468	.690	.863
	Total without heat recovery					4,327,700				19,091	5326	28.117	7.484	18,074	27.152	95.721
UNITS WITH HEAT RECOVERY																
1	N. West	Chicago, IL	Starved air reciprocating (3)	ESP (3)	1600 (3) 365 d/y (3)	584,000^{c}	90% Assumed			2000	200	2.95	.295	876	1.29	12.9
2	Baltimore	Baltimore, MD	Rotating kiln (3)	ESP (3)	1000 (3) 7 d/w	364,000^{c}	90% Assumed			1250	125	1.84	.184	546	.805	8.05
3	Resco	Saugus, MA	Starved air traveling gate (3)	ESP (3)	1200 365 d/y	438,000^{c}	90% Assumed	NSPS, In compliance, particulate source test		1500	150	2.21	.221	657	.969	9.69
4	Braintree	Braintree, MA		ESP-Assumed	240, 5 d/w	62,400^{c}	90%-Assumed			300	30	.442	.044	842	1.242	1.38
5	Betts	New York, NY		ESP-Assumed	1000, 5 d/w Assumed	260,000	90%-Assumed	SIP, in violation, mtg. sched.	103 #/hr	1250	125	1.84	.184	390	.575	5.75
6	Hempstead	Hempstead, NY	Water wall reciprocating (3)	ESP (3)	1 @ 600 1 @ 750 7 d/w (3)	491,400^{c}	90% Assumed	SIP, In compliance, source test		1687	168	2.49	.249	737	1.09	10.9
7	S. West	Brooklyn, NY	Cascading	ESP (3)	600 (3)	SHUTDOWN (5)										
8	Harrisburg	Harrisburg, PA	Starved air reciprocating (3)	ESP (3)	720 (3) 365 d/y	262,800^{c}	90% Assumed			900	90	1.33	.133	394	.581	5.81
9	Nashville	Nashville, TN	Starved air reciprocating (3)	ESP (3)	720 (3) 365 d/y	262,800^{c}	90% Assumed	NSPS, In compliance, source test		900	90	1.33	.133	394	.581	5.81
10	Norfolk Navy Public Works	Norfolk, VA	Starved air reciprocating (3)	ESP (3)	360 (3) 7 d/w (3)	131,040^{c}										
11	Waukesha	Waukesha, WI	Refratory wall (3) reciprocating	ESP (3)	110 (3) 5 d/w-Assumed	28,600^{c}	90% Assumed			137	13.8	.203	.020	43	.063	.632
	Total with heat recovery					2,885,040				9924	991.8	14.635	1.463	4879.9	7.196	60.922
	Total with and without heat recovery					7,212,740				29,015	6317.8	42.752	9.311	22,954	34.348	156.643

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Footnotes for Table 4.4-2a and Table 4.4-2b

(1) Carcinogens From Municipal Incinerators Draft Report, Wapora, Inc., August 4, 1980.

(2) Memo to Ron Meyers, USEPA/ESED, from Henry Modetz, Acurex Corporation, Results of Municipal Incinerator Survey, March 18, 1980.

(3) Telecons by Acurex Corporation, Survey completed and summarized March 18, 1980.

(4) Personal Communication, Ron Meyers, USEPA/ESED, with Timothy Curtin, GCA/Technology Division, January 22, 1981.

(5) Compliance Data System, Quick Look Report.

c = calculated.

A recent trend in municipal incineration is toward the use of package units. These units vary in design size from 8.2-27.2 Mg per day (9-30 TPD). Frequently multiple units are placed together in one location. Figure 4.4-2 presents a diagram of two such units at one location. The package includes the refuse handling equipment, the incinerator itself, emission control equipment, and standard hook-ups for utilities (i.e, water, electricity, gas). The modular design of package units allows a facility to increase its capacity by purchasing an additional self contained unit similar to the existing equipment. Table 4.4-3 presents a list of operating locations and capacity for the package incinerators in the United States.

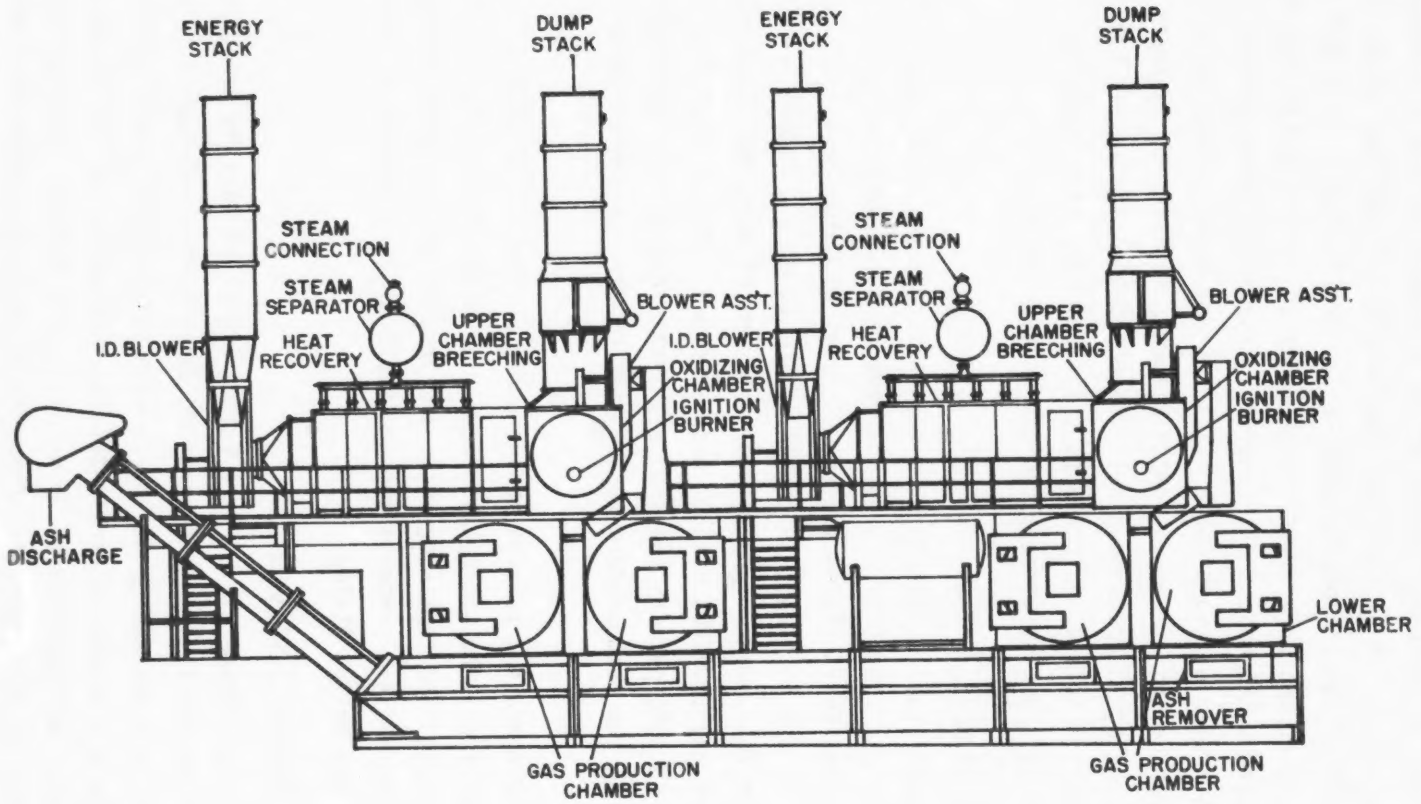
4.4.3 Geographical Distribution

Of the 44 municipal incinerators in the United States with capacities above 45.4 mg per day (50 PTPD), 33 do not have heat recovery capabilities. These 33 are located in 14 states and the District of Columbia and all but six are located in the northeastern corner of the country. Figure 4.4-3 presents a map of the number of operating locations of municipal incinerators above 45.4 Mg per day (50 TPD) without heat recovery. The 11 operating locations above 45.4 Mg per day (50 TPD) with heat recovery are also located in eight states in the northeastern part of the country as presented in Figure 4.4-4.

There are 90 operating package incinerators in the United States. Almost one third of all the package incinerators in the United States are located in Arkansas. The remaining units are located in 12 states throughout the country. Figure 4.4-5 presents the geographical distribution of package incinerators in the United States.

4.4.4 Emission Control Techniques

Every municipal incinerator in the United States of 45.4 Mg per day (50 TPD) or greater utilizes some type of emission control equipment. The equipment varies from low energy scrubbers with particulate removal efficiencies of 20 percent, to electrostatic precipitators, baghouses, and scrubbers with particulate removal efficiencies of 99 percent. The average industry-wide control efficiency is 76.4 percent. Other types of control equipment which are used on municipal incinerators include: settling chambers, cyclones, and multiclones. Table 4.4-2 lists the control equipment for the municipal incinerators of 45.4 Mg per day (50 TPD) or greater.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DUMP STACK
ENERGY STACK
DUMP STACK
STEAM CONNECTION
STEAM SEPARATOR
STEAM CONNECTION
STEAM SEPARATOR
BLOWER ASS'T.
BLOWER ASS'T.
I.D. BLOWER
HEAT RECOVERY
UPPER CHAMBER BREECHING
I.D. BLOWER
HEAT RECOVERY
UPPER CHAMBER BREECHING
OXIDIZING CHAMBER
IGNITION BURNER
OXIDIZING CHAMBER
IGNITION BURNER
ASH DISCHARGE
LOWER CHAMBER
ASH REMOVER
GAS PRODUCTION CHAMBER
GAS PRODUCTION CHAMBER

Figure 4.4-2. Two package incinerators at one location.[15]

TABLE 4.4-3a PACKAGE INCINERATORS*

(Metric units)

Manufacturer	Operating location	No.	Capacity per unit Mg/day	Plant capacity Mg/day	Year of instal-lation	Heat recovery	Mg per year	Controlled particulate Kg/hr	Controlled cadmium Kg/hr	Controlled particulate Mg/yr	Controlled cadmium Mg/yr
U.S. Smelting	Crossville, TN	2	27.2	54.4	1976	yes	5,561	2.29	.039	5.72	.100
Kelley	Nottingham, NH	1	8.2	8.2	1975	no	849	0.34	.006	0.86	.015
	Candia, NH	1	12.7	12.7	1976	no	1,321	0.53	.009	1.33	.024
	Bridgewater, NH	1	12.7	12.7	1976	no	1,321	0.53	.009	1.33	.024
	Meredith, NH	2	12.7	25.4	1976	no	2,642	1.07	.018	2.67	.046
	Canterbury, NH	1	8.2	8.2	1977	no	849	0.34	.006	0.86	.015
	Pittsfield, NH	1	12.7	12.7	1977	no	1,321	0.53	.009	1.33	.024
	Kittery, ME	2	21.8	43.5	1977	no	4,529	1.83	.031	4.57	.080
	Harpswell, ME	1	12.7	12.7	1977	no	1,321	0.53	.009	1.33	.024
	Auburn, NH	1	12.7	12.7	1978	no	1,321	0.53	.009	1.33	.024
Consumat	Stuttgart, AR	2	27.2	54.4	1972	no	5,561	2.29	.039	5.72	.100
	Augusta, AR	1	20.0	20.0	1972	no	2,076	0.84	.015	2.10	.036
	Tahlequah, OK	2	27.2	54.4	1972	no	5,561	2.29	.040	5.72	.100
	Donaldsonville, LA	1	27.2	27.2	1972	no	2,830	1.15	.020	2.86	.050
	Rayne, LA	2	27.2	54.4	1973	no	5,561	2.29	.040	5.72	.100
	Plaquemine, LA	2	27.2	54.4	1973	no	5,561	2.29	.040	5.72	.100
	Kensett, AR	1	14.5	14.5	1973	no	1,510	0.61	.010	1.52	.026
	Skaneateles, NY	1	27.2	27.2	1973	no	2,830	1.15	.020	2.86	.050
	Osceola, AR	2	27.2	54.4	1974	no	5,561	2.29	.040	5.72	.100
	Cleveland, OK	1	20.0	20.0	1974	no	2,076	0.84	.015	2.10	.036
	Pahokee, FL	2	20.0	40.0	1974	no	4,151	1.68	.029	4.19	.073
	Orlando, FL	8	27.2	217.7	1974	no	22,643	9.16	.160	22.87	.396
	Refugio, TX	1	20.0	20.0	1974	no	2,076	0.84	.015	2.10	.036
	Bellingham, WA	8	11.8	94.3	1974	no	9,812	3.97	.069	9.91	.171
	Terrell, TX	3	16.3	49.0	1975	no	5,095	2.06	.034	5.14	.089
	Hot Springs, AR	8	27.2	217.7	1975	no	22,643	9.16	.160	22.87	.396
	Bentonville, AR	2	27.2	54.4	1975	no	5,561	2.29	.040	5.72	.100
	Hope, AR	2	27.2	54.4	1975	no	5,561	2.29	.040	5.72	.100
	Siloam Springs, AR	2	20.0	40.0	1975	yes	4,151	1.68	.029	4.19	.073
	Blytheville, AR	4	16.3	65.3	1975	yes	6,793	2.75	.048	6.86	.120
	Wrightsville Beach, NC	2	27.2	54.4	1977	no	5,561	2.29	.040	5.72	.100

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TABLE 4.4-3a * (continued)

Manufacturer	Operating location	No.	Capacity per unit Mg/day	Plant capacity Mg/day	Year of instal-lation	Heat recovery	Mg per year	Controlled particulate Kg/hr	Controlled cadmium Kg/hr	Controlled particulate Mg/yr	Controlled cadmium Mg/yr
Consumat	Tahlequah, OK	2	27.2	54.4	1977	no	5,561	2.29	.040	5.72	.100
	Coos County, OR	1	27.2	27.2	1977	no	2,830	1.15	.020	2.86	.050
	N. Little Rock, AR	4	22.7	90.7	1977	no	18,506	3.82	.066	9.52	.166
	Port Orange, FL	4	27.2	108.9	1978	no	11,322	4.58	.079	11.43	.200
	Atkins, AR	1	15.4	15.4	1978	no	1,604	0.65	.011	1.62	.028
	Wilton, NH	1	27.2	27.2	1978	no	2,830	1.15	.020	2.86	.050
	Litchfield, NH	1	20.0	20.0	1978	no	2,076	0.84	.015	2.10	.036
	Wolfeboro, NH	1	16.3	16.3	1978	no	1,698	0.69	.012	1.71	.030
	Coos County, OR	1	27.2	27.2	1978	no	2,830	1.15	.020	2.86	.050
	Salem, VA	4	22.7	90.7	1978	yes	9,435	3.82	.066	9.52	.166
		90		1,969.3			212,901	82.87	1.437	206.86	3.604

[a] Based on 8 hr/day, 6 days/week, 52 weeks/year.

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TABLE 4.4-3b PACKAGE INCINERATORS*

(English units)

Manufacturer	Operating location	No.	Capacity per unit TPD	Plant capacity TPD	Year of instal-lation	Heat recovery	Tons per year	Controlled particulate #/hr	Controlled cadmium #/hr	Controlled particulate T/yr	Controlled cadmium T/yr
U.S. Smelting	Crossville, TN	2	30	60	1976	yes	6,240	5.05	.088	6.30	.110
Kelley	Nottingham, NH	1	9	9	1975	no	936	.758	.013	.95	.016
	Candia, NH	1	14	14	1976	no	1,456	1.18	.021	1.47	.026
	Bridgewater, NH	1	14	14	1976	no	1,456	1.18	.021	1.47	.026
	Meredith, NH	2	14	28	1976	no	2,912	2.36	.041	2.94	.051
	Canterbury, NH	1	9	9	1977	no	936	.758	.013	.95	.016
	Pittsfield, NH	1	14	14	1977	no	1,456	1.18	.021	1.47	.026
	Kittery, ME	2	24	48	1977	no	4,992	4.04	.070	5.04	.088
	Harpswell, ME	1	14	14	1977	no	1,456	1.18	.021	1.47	.026
	Auburn, NH	1	14	14	1978	no	1,456	1.18	.021	1.47	.026
Consumat	Stuttgart, AR	2	30	60	1972	no	6,240	5.05	.088	6.30	.110
	Augusta, AR	1	22	22	1972	no	2,288	1.85	.032	2.31	.040
	Tahlequah, OK	2	30	60	1972	no	6,240	5.05	.088	6.30	.110
	Donaldsonville, LA	1	30	30	1972	no	3,120	2.53	.044	3.15	.055
	Rayne, LA	2	30	60	1973	no	6,240	5.05	.088	6.30	.110
	Plaquemine, LA	2	30	60	1973	no	6,240	5.05	.088	6.30	.110
	Kensett, AR	1	16	16	1973	no	1,664	1.35	.023	1.68	.029
	Skaneateles, NY	1	30	30	1973	no	3,120	2.53	.044	3.15	.055
	Osceola, AR	2	30	60	1974	no	6,240	5.05	.088	6.30	.110
	Cleveland, OK	1	22	22	1974	no	2,288	1.85	.032	2.31	.040
	Pahokee, FL	2	22	44	1974	no	4,576	3.70	.065	4.62	.080
	Orlando, FL	8	30	240	1974	no	24,960	20.2	.352	25.21	.437
	Refugio, TX	1	22	22	1974	no	2,288	1.85	.032	2.31	.040
	Bellingham, WA	8	13	104	1974	no	10,816	8.75	.153	10.92	.189
	Terrell, TX	3	18	54	1975	no	5,616	4.55	.076	5.67	.098
	Hot Springs, AR	8	30	240	1975	no	24,960	20.2	.352	25.21	.437
	Bentonville, AR	2	30	60	1975	no	6,240	5.05	.088	6.30	.110
	Hope, AR	2	30	60	1975	no	6,240	5.05	.088	6.30	.110
	Siloam Springs, AR	2	22	44	1975	yes	4,576	3.70	.065	4.62	.081
	Blytheville, AR	4	18	72	1975	yes	7,488	6.06	.105	7.56	.132
	Wrightsville Beach, NC	2	30	60	1977	no	6,240	5.05	.088	6.30	.110

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TABLE 4.4-3b * (continued)

Manufacturer	Operating location	No.	Capacity per unit TPD	Plant capacity TPD	Year of instal-lation	Heat recovery	Tons per year[a]	Controlled particulate #/hr	Controlled cadmium #/hr	Controlled particulate T/yr	Controlled cadmium T/yr
Consumat	Tahlequah, OK	2	30	60	1977	no	6,240	5.05	.088	6.30	.110
	Coos County, OR	1	30	30	1977	no	3,120	2.53	.044	3.15	.055
	N. Little Rock, AR	4	25	100	1977	no	20,400	8.42	.146	10.50	.183
	Port Orange, FL	4	30	120	1978	no	12,480	10.1	.176	12.60	.220
	Atkins, AR	1	17	17	1978	no	1,768	1.43	.025	1.79	.031
	Wilton, NH	1	30	30	1978	no	3,120	2.53	.044	3.15	.055
	Litchfield, NH	1	22	22	1978	no	2,288	1.85	.032	2.31	.040
	Wolfeboro, NH	1	18	18	1978	no	1,872	1.52	.026	1.89	.033
	Coos County, OR	1	30	30	1978	no	3,120	2.53	.044	3.15	.055
	Salem, VA	4	25	100	1978	yes	10,400	8.42	.146	10.50	.183
TOTAL		90		2,171			235,784	182.766	3.18	227.99	3.969

[a] Based on 8 hr/day, 6 days/week, 52 weeks/year.

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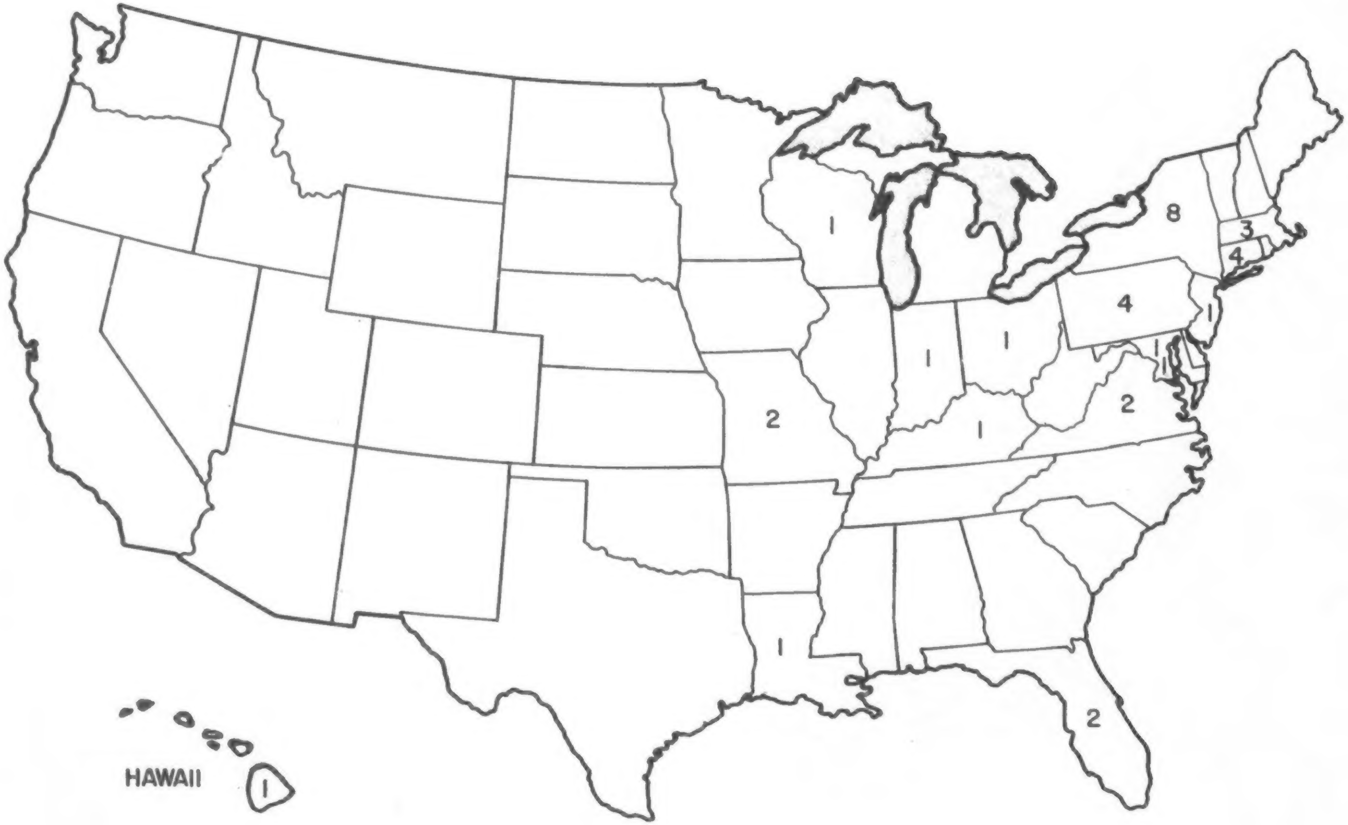
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Figure 4.4-3. Geographical distribution of conventional incinerators without heat recovery.

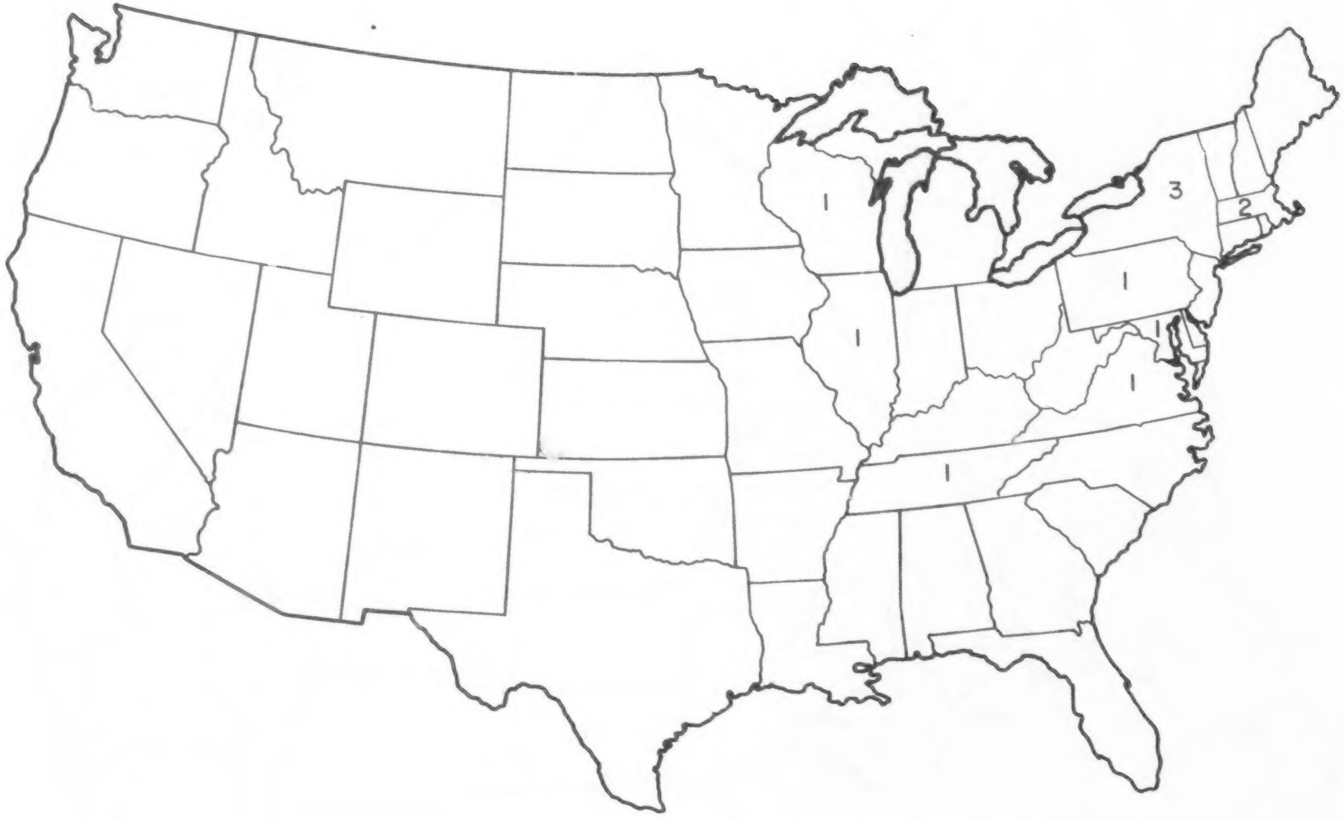
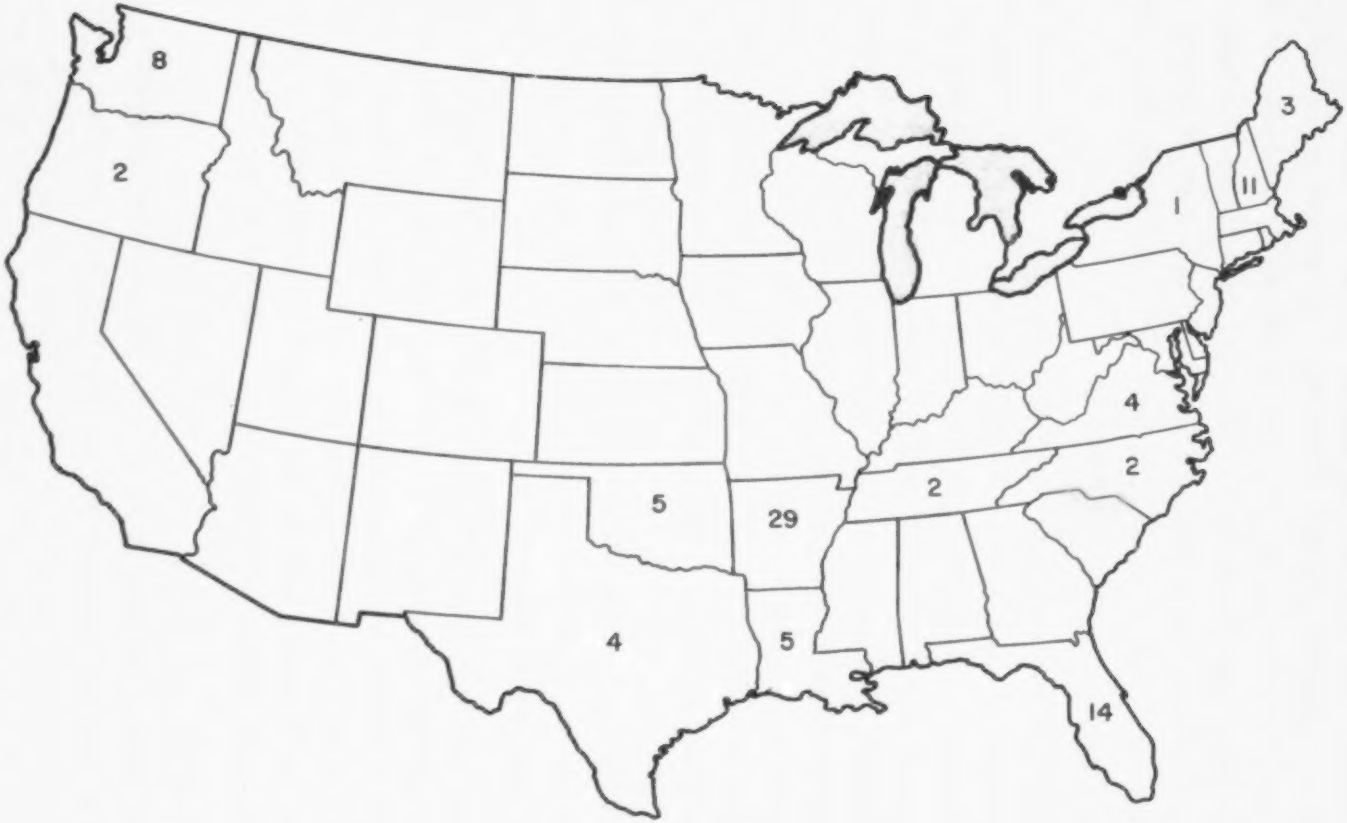


Figure 4.4-4 Geographical distribution of conventional incinerators with heat recovery.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4
2
2
5
29
4
5
14

Figure 4.4-5. Geographical distribution of package incinerators.

Package incinerators typically include emission control equipment as an integral part of the package and the incinerator itself. Normally, the control equipment is a secondary combustion chamber fitted with an afterburner. In the primary combustion chamber, the refuse is ignited producing off gases with heavy combustible particulate loadings and volatile gases. In the secondary chamber, the afterburner ignites the combustible fractions of the off gases and reduces the particulate loading. This type of control technique has been shown to reduce total particulate emissions but may be ineffective in removing cadmium and other trace metals.

Cadmium, when emitted from municipal incinerators, is found in the smaller particles. About 80 percent of the cadmium is associated with particles less than three microns in size and 50 percent is associated with particles less than one micron in size. Figure 4.4-6 presents particle size curves for total particulate and cadmium. These curves were derived by in-stack particle sizing tests followed by chemical analysis for cadmium.[10] The median particle size for total particulate is 3.3 microns but for cadmium it is 0.96 microns. Consequently, to remove one half of the cadmium, particulate matter larger than 0.96 microns has to be removed. However, to remove one half of the total particulate, only particulate matter larger than 3.3 microns has to be removed. Therefore, higher efficiency particulate control equipment is required to remove a specific percentage of cadmium than to remove the same percentage total particulate.

Two explanations have been advanced to account for cadmium's tendency toward the smaller submicron particle sizes. The first is that cadmium in the combustion chamber exists as cadmium oxide fumes which are typically submicron in size. The other explanation is that cadmium is selectively adsorbed on smaller particles in the incinerator gases because of their higher surface to volume ratios relative to the larger particles.[11]

4.4.5 Emissions

Annual controlled cadmium emissions from municipal incinerators are 34.7 Mg (38.3 tons). Conventional incinerators with capacities above

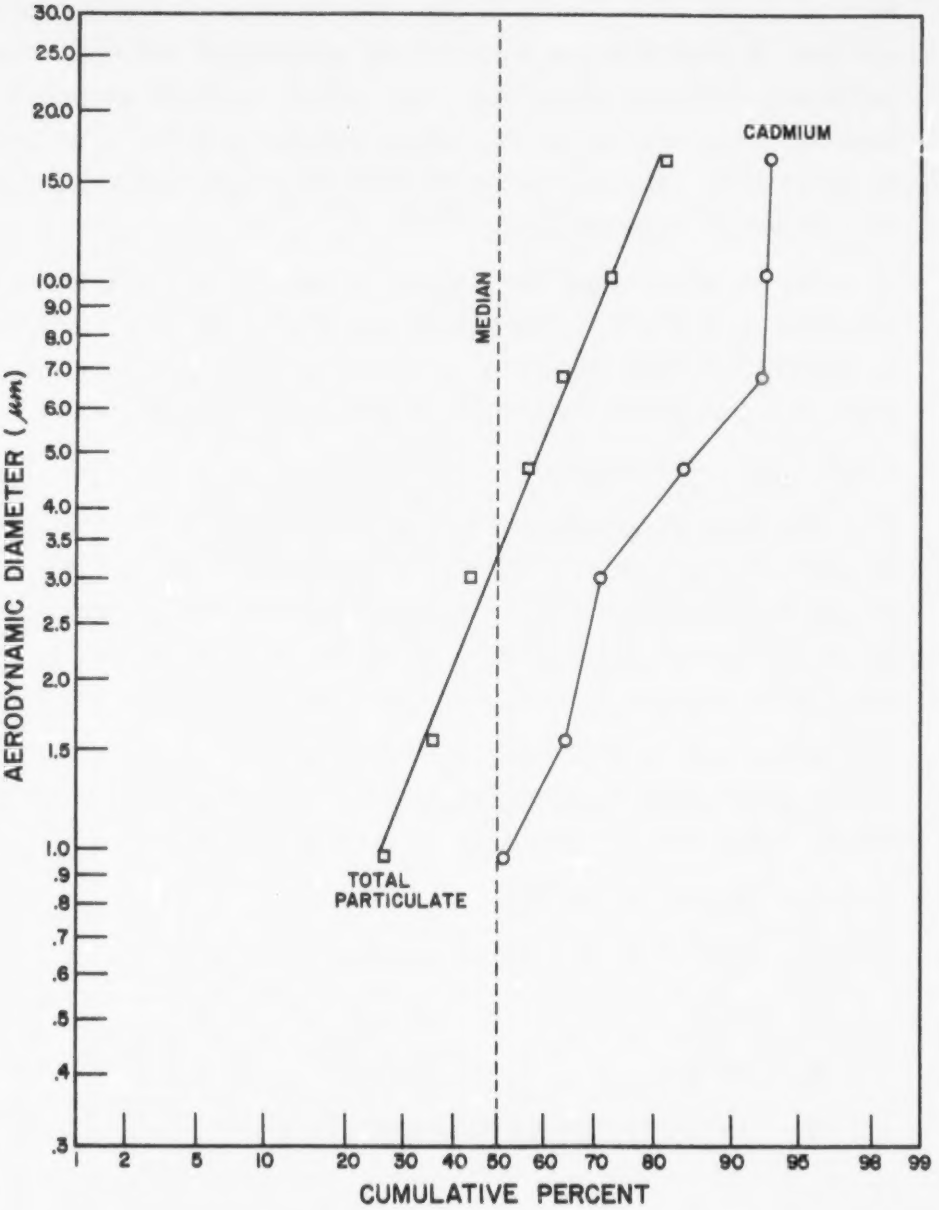

Figure 4.4-6. Particle size distribution of the emissions from a municipal incinerator.

45.4 Mg/day (50 TPD) accounted for 31.1 Mg (34.3 tons) controlled. Package incinerators accounted for 3.6 Mg (4.0 tons) per year controlled cadmium emissions.

Emissions from conventional incinerators are presented in Table 4.4-2. Because of the wide variety of municipal refuse, an average emission factor was used to determine the uncontrolled particulate emission rates.[12] To calculate controlled emissions, site-specific control equipment efficiencies were used. Cadmium emissions were calculated by applying an average cadmium to particulate ratio to the particulate emissions. This ratio is the result of a number of emission tests.[13,14]

The emission values for cadmium and particulate from package incinerators presented in Table 4.4-3 were developed from a set of emissions tests conducted by the EPA.[15] Both controlled particulate and cadmium emission factors were developed from these tests and were applied to each operating location.

4.4.6 Compliance Status*

The compliance status of conventional municipal incinerators for units at or above 45.4 Mg per day (50 TPD) is presented in Table 4.4-2. The compliance status reported in this table was obtained from EPA's Compliance Data System's Quick Look Report.[16] According to that report, 19 facilities are in compliance and eight are in violation. The remaining 18 units are not listed.

There are eleven sets of English units which are presently utilized to define particulate emission limitations from municipal incinerators in the United States. All eleven sets of units are listed below:[17]

1. gr/scf at 12% CO_2
2. lb/100 lb. dry refuse charged
3. lb/hr
4. gr/scf
5. lb/100 lb. gas at 50% excess air

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

6. lb/hr per lb/hr charge
7. lb/100 lb. gas
8. gr/scf at 7% O_2
9. gr/scf at 50% excess air
10. lb/10^6 btu
11. lb/1000 lb. gas at 12% CO_2

In addition to the particulate emission regulations, all States have opacity limitations for compliance determinations.[18] However, emissions testing is required to determine actual emission rates.

4.4.7 Comparison of National Emission Estimates with Other Studies

A number of different studies have reported estimates of national cadmium emissions from municipal incinerators. The present study utilized a site-specific methodology incorporating emission control equipment and associated efficiencies to estimate annual cadmium emissions to be 34.7 Mg (38.3 tons). In previous studies, Energy and Environmental Analysis estimated 118 Mg (131 tons), Davis and Mitre both estmated 86.1 Mg (95 tons), EPA estimated 43.5 Mg (48 tons), and Sargent estimated 14.5 Mg (16 tons).[19]

A number of reasons exist for the differences in these emission estimates. Many old uncontrolled facilities have been shut down or replaced with modern units with emission controls. Emission factors can vary considerably due to the variability of the refuse itself. During this study, an averaged emission factor was used.

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4.5 SLUDGE INCINERATION

4.5.1 Introduction

Sludge incineration is a two-step process involving drying and combustion. The purpose of incineration is to reduce the total volume of the sludge, to destroy all organic matter by complete combustion, to destroy all pathogenic organisms, and produce an odor free end product. Typical sludge is 80 percent water and 20 percent solids. Of this 20 percent, 75 percent are combustible. Following incineration, dry solids are reduced to 20 to 25 percent of the solids entering the unit. The reduction of sludge volume reduces the land requirements for disposal. Incinerators are located in urban areas at plants that are long distances from land or ocean disposal sites, or where regulations prohibit these alternate disposal methods. In addition, the large amount of mechanical and electrical equipment used in the process limits incinerators to large plants with full-time maintenance staffs. For these reasons, the 1.8 percent of the U.S. plants that have incinerators, incinerate 23.6 percent of the sludge produced nationwide.

Sludge is incinerated at 358 wastewater treatment plants. Of the 358 plants, 320 use multiple-hearth units, 15 use fluidized-bed units, seven use rotary kiln units, two use pyrolysis, four use co-incineration with municipal refuse, and ten use some other method.[1]

Wastes containing cadmium are discharged to municipal wastewater treatment plants by industrial or commercial sources, with the principal contributions of cadmium coming from metal plating processes. Cadmium is also used in pigment manufacture, photographic applications, dyeing, and calico printing.[2]

4.5.2 Process Description

The two common types of incinerators are multiple hearth and fluidized bed. These two processes are used on approximately 94 percent of the sludge which is incinerated in the U.S.[1]

4.5.2.1 Multiple-hearth Furnace[3] The multiple-hearth furnace (MHF) is the most widely used type of sludge incinerator in the U.S.[1] The MHF is a vertically oriented, cylindrically shaped, refractory-lined, steel shell containing a series of refractory hearths, one above the other. Multiple-hearth furnaces are available with diameters ranging from 1.37 m (4.5 ft) to 8.84 m (29 ft) with four to fourteen hearths. A typical section of a MHF is shown in Figure 4.5-1.

A central shaft extends the entire height of the furnace and supports rabble arms above each hearth. The rabble arms rake the sludge spirally across the hearth and break up the large sludge particles to induce rapid and complete combustion. Sludge is fed at the periphery of the top hearth and is raked inward then outward on alternate hearths.

Since the operating temperature on the hearth may reach 1100°C (2000°F), the central shaft and rabble arms are cooled with compressed air fed from the bottom. A portion of the cooling air is drawn from the top of the furnace and returned to the furnace bottom to serve as preheated combustion air. Excess air requirements for the MHF may vary from 50 to 100 percent.

The MHF can be divided into three operating zones. The first zone, which consists of the upper hearths, is the drying zone where most of the water is evaporated; the second zone, generally consisting of the central hearths, is the combustion zone, where temperatures reach 760° to 927°C (1400° to 1700°F) and carbon is oxidized to carbon dioxide; and the third zone is the cooling zone, which includes the lowest hearths. In this zone, the ash is cooled by the incoming combustion air. The sequence of zones is always the same, but the number of hearths in each zone is dependent upon the quality of the feed, the design of the furnace, and the operational conditions.

For sludge containing greater than 75 percent moisture, autogenous combustion cannot be sustained and auxiliary fuel burners, using gas or oil, supply the additional heat by operating either continuously or intermittently on all or selected hearths. Generally, off gas temperatures of 315°C (600°F), or lower, indicate incomplete combustion and a need for supplemental fuel. Off gas temperatures from 427° to 871°C (800° to 1600°F) indicate complete combustion.

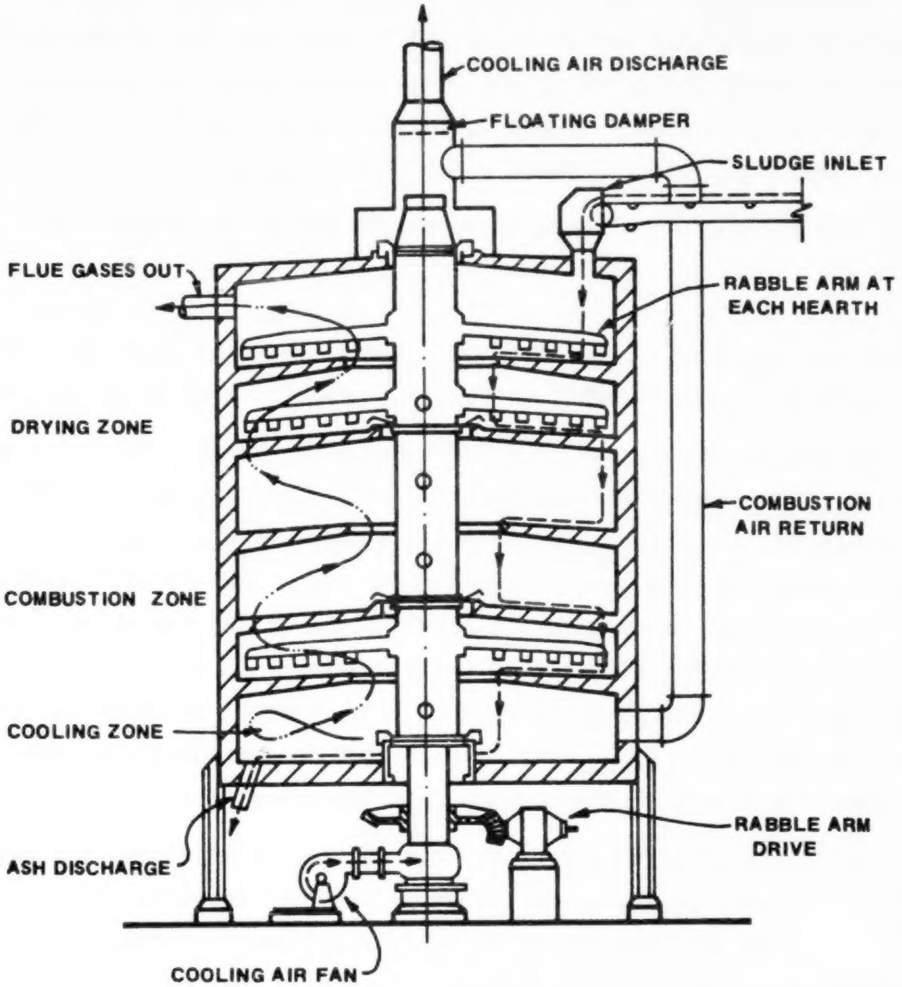
COOLING AIR DISCHARGE
FLOATING DAMPER
SLUDGE INLET
FLUE GASES OUT
RABBLE ARM AT EACH HEARTH
DRYING ZONE
COMBUSTION AIR RETURN
COMBUSTION ZONE
COOLING ZONE
RABBLE ARM DRIVE
ASH DISCHARGE
COOLING AIR FAN

Figure 4.5-1 Cross section of a typical multiple hearth incinerator.

Ash drops from the bottom hearth and is either sluiced away or disposed of in dry form. Exhaust gases from the top hearth must be scrubbed to remove particulates.

4.5.2.2 Fluidized-bed Furnace [3] The fluidized-bed furnace (FBF) is a vertically oriented cylindrically shaped, refractory-lined, steel shell which contains the bed and fluidizing air diffusers. The FBF is normally available in sizes from 2.74 m (9 ft) to 7.62 m (25 ft) in diamter. A cross section of the fluid-bed furnace is shown in Figure 4.5-2. The sand bed is approximately 0.76 m (2.5 ft) thick and sits on a refractory-lined grid. This grid contains tuyeres through which air is injected into the bed at a pressure of 20.6 kPa to 34.4 kPa. (3 to 5 lb/sq in) to fluidize the bed. Bed expansion is approximately 80 to 100 percent. Temperature of the bed is controlled between 760° and 815°C (1400 and 1500°F) by auxiliary burners located either above or below the sand bed. Ash is carried out of the top of the furnace and is removed by air pollution control devices, usually wet venturi scrubbers. The sewage sludge is fed directly into the bed.

Excess air requirements for the FBF vary from 20 to 40 percent versus 50 to 100 percent for the multiple hearth furnace. The lower air requirement of the FBF results in reduced heat loss and reduced supplemental fuel usage as compared to the MHF. The mixing action caused by the air flowing through the bed and the injection of sludge directly into the bed ensures complete contact between the sludge solids and the combustion gases.

The FBF has two basic configurations. In the first system, the fluidizing air passes through a heat exhanger or recuperator to preheat air prior to injection into the combustion chamber. This system is known as a hot windbox. In the second system which is known as a cold windbox, the fluidizing air is injected directly into the furnace. The preheating in the hot wind box system substantially reduces auxiliary fuel costs but it also requires an increase in capital investment.

4.5.3 Geographic Distribution

As previously noted, sludge incinerators are located primarily in urban areas at plants located long distances from land or ocean disposal sites, or where regulations prohibit alternate disposal methods. Thus, sludge incinerators are located primarily in metropolitan areas throughout the U.S.

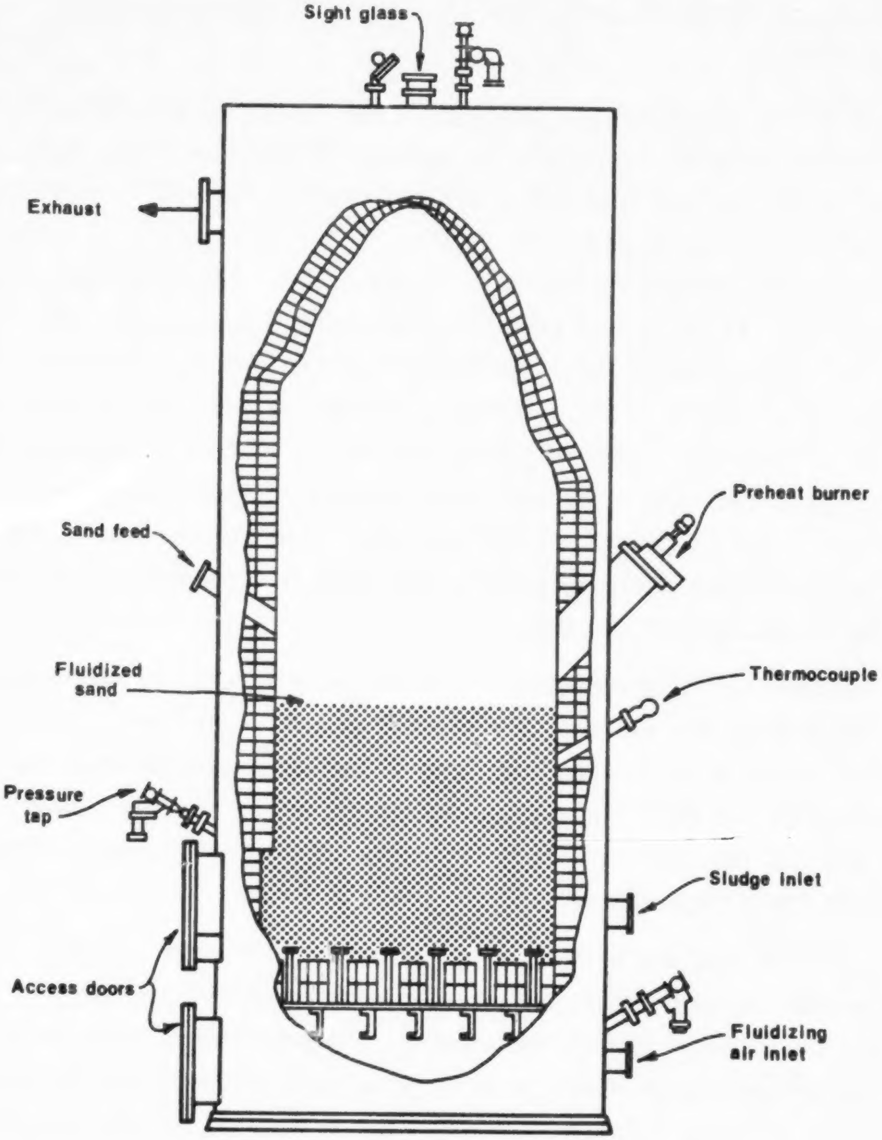
Sight glass
Exhaust
Preheat burner
Sand feed
Fluidized sand
Thermocouple
Pressure tap
Sludge inlet
Access doors
Fluidizing air inlet

Figure 4.5-2 Cross section of a fluid bed reactor.

4.5.4 Emission Control Techniques

To clean sludge incinerator exhaust gases, incinerators are usually equipped with wet scrubbers. Scrubber types include wet cylone, impingement, venturi, and venturi-impingement. Mechanical collectors may possibly be used on some existing modified units, but to comply with particulate standards, a mechanical collector must be augmented by a wet collection system. Both venturi and impingement types of scrubbers have successfully met particulate emission standards.[4]

4.5.5 Emissions

Particulate emissions into the atmosphere are almost entirely a function of scrubber efficiency and are only minimally affected by incinerator conditions, although emissions will increase if design temperatures are not maintained, or if excess sludge is fed into the incinerator. Uncontrolled multiple-hearth incinerator gases contain about 20 g of particulate per kg of dry sludge. Scrubbers need a particulate removal efficiency of approximately 97 percent to meet the NSPS particulate standard.

Cadmium emissions from sludge incinerators have not been extensively documented. In three separate heavy metal mass balances at fluidized bed sludge incinerators, it was found that less than 0.1 percent of the cadmium in the sludge was emitted to the atmosphere. Uncontrolled cadmium emissions were not reported.[5]

In a study of eight multiple hearth incinerators and two fluidized bed units, it was reported that cadmium emissions to the atmosphere averaged 17.9 percent of the cadmium in the sludge.[6] Values ranged from 0 to 35.9 percent. As with other high temperature sources, the emitted cadmium was associated with particles in the 0.1 to 1.0 micron sizes.

A determination of annual cadmium emissions was made by first calculating the average sludge production per million gallons of wastewater. Using data from 27 wastewater plants with sludge incinerators,[7] an average of 0.58 Mg (0.64 tons) of sludge is produced for each million gallons of wastewater. The values ranged from 0.023 to 1.38 Mg (0.025 to 1.52 tons) per million gallons. Secondly, an average cadmium concentration of 56.85 mg/kg sludge was computed from twenty data points.[7] Cadmium concentrations ranged from 6 to 240 mg/kg. Multiplying these numbers by the total daily wastewater flow of 6.19×10^9 gallons for facilities with incinerators, yielded 0.20 Mg (0.22 tons) of cadmium per day in the incinerator sludge, or 73 Mg (80 tons) per year. Using the reported value of 17.9 percent emitted, results in an annual cadmium emission from sludge incinerators of 13 Mg (14.3 tons).

4.5.6 Compliance Status*

A New Source Performance Standard (NSPS) for sewage sludge incinerators was promulgated in 1973 and ammended in 1977. The standard limits particulate matter emissions to 0.65 grams per kilogram (1.3 #/Ton) of dry sludge input and limits the opacity to 20 percent.

A survey of current State air quality control regulations was performed during the 1978 review of the NSPS[8] to identify differences between the NSPS and State regulations.

Twenty two states have adopted the Federal NSPS for sewage sludge incinerators. Maryland's NSPS for particulate emissions of 0.03 grains/dscf at 12 percent CO_2 may be more stringent than the 1.3 lb/dry ton input standard. The remaining States either have standards less strict for new sewage sludge incinerators or have general incineration standards that do not explicitly reference sewage sludge. None of the States have explicit standards for existing sewage sludge incinerators. Of those States having general incineration standards, the standard level, wording and description of the testing procedures indicate that the standards apply mainly to characteristics associated with municipal incineration of solid waste and not to the special case sewage sludge incinerators. No State has a standard for the joint incineration of municipal sewage sludge and solid waste.

Many States use a categorization of waste as adopted from the National Solid Wastes Management Association (NSWMA) as a basis for emission standards for each waste category. This categorization is incomplete in that the sludge from municipal wastewater treatment is not described in the NSWMA categorizations. It is, therefore, difficult to identify what emission standard would be applied to operating a sewage sludge incinerator within the State. Many States have incinerator standards that require new incinerators to be multichambered, operate at minimum temperatures ranging from 689° to 871°C (1200° to 1600°F), and have minimum retention times of 0.3 seconds or greater. These standards appear to be written for municipal solid waste disposal incinerators but, as discussed above, may also apply to general incineration processes including sewage sludge. It also appears that several States depend on the National Solid Waste Management Association waste categorization or application of incineration emission standards, and sewage sludge is not included in the NSWMA categories.

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

Useful information on the compliance status of the 358 sludge incinerators is unavailable at this time.

4.5.7 Comparison of National Emission Estimates with Other Studies

Measurements of sludge production, cadmium concentrations in sludge, cadmium emissions, and daily wastewater flow were combined to calculate an annual cadmium emission from sludge incinerators of 13 Megagrams (14.4 Tons). In previous studies, Energy and Environmental Analysis estimated less than 1 Mg (less than 1 ton); EPA estimated 125 Mg (138 Tons); GCA estimated 11 Mg (12 Tons); and Sargent estimated 18 Mg (20 Tons).[9]

Differences in the estimates are due to different assumptions on control devices, sludge production, and total number of incinerators.

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4.6 IRON AND STEEL INDUSTRY

Airborne cadmium emissions from the iron and steel (I&S) industry are generated by the use of raw materials which contain cadmium. Scrap metal, iron ores, and coal contain small concentrations of cadmium. Cadmium is not used as an alloy material. Cadmium is used for electroplating and is used in trace amounts in conjunction with galvanizing. None of these operations is a significant source of cadmium emissions. Since most iron and steel processes operate at temperatures well above the boiling point of cadmium, most of the cadmium is volatilized and emitted with process off gases.

This section discusses the levels of cadmium emitted from the I&S industry. The I&S industry is defined as all producers of coke, iron, steel, specialty steel, and cast iron. National cadmium emissions have been estimated by the use of the industry-wide consumption of raw materials and their cadmium contents. Where available, emission factors generated from emissions tests were utilized. To help identify and quantify individual emission points, model plants were developed. Also included in this section is a description of iron and steel making processes, emission control techniques, a discussion of the compliance status of the industry, and a comparison of national emissions estimates with other studies.

4.6.1 Process Description

4.6.1.1 General. Coke is used in steel mills and iron foundries to provide the heat necessary to produce molten iron. Coke is either hauled to the steel mill or made in a coke facility at the steel mill, Coke, limestone, and iron ore are combined in the blast furnace. The blast furnace produces molten iron. Molten iron is removed from the blast furnace and transferred to the steel making furnaces. Scrap metal is commonly mixed with the molten iron in the steel furnaces. The whole mix is then made into steel by heat-refining the metal and adding alloying materials and fluxes. The molten steel is cast into various shapes, then sent through a finishing process. Figure 4.6-1 illustrates the process flows for an integrated steel mill representing the iron and steel industry.

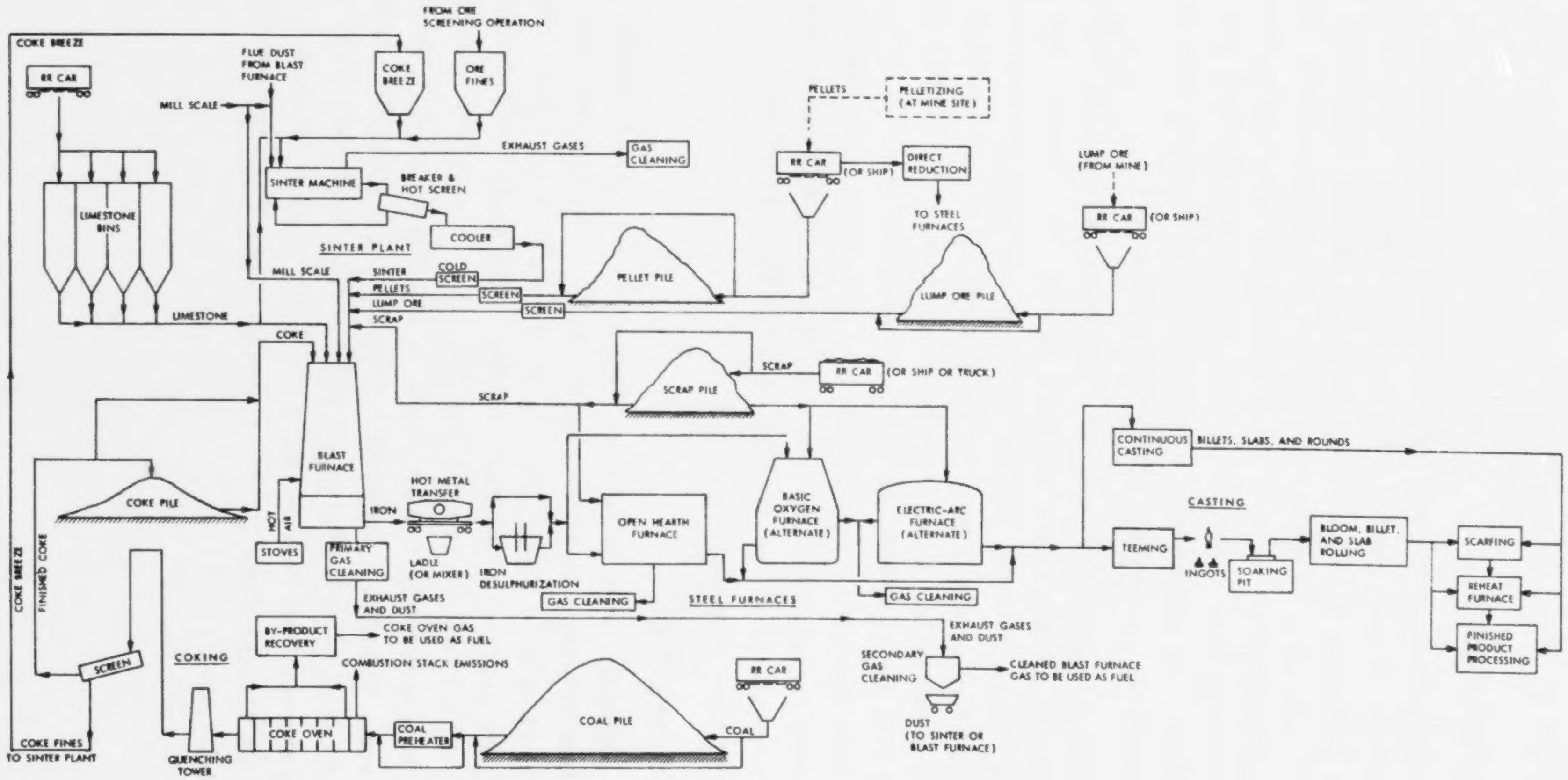

COKE BREEZE
RR CAR
LIMESTONE BINS
LIMESTONE
MILL SCALE
FLUE DUST FROM BLAST FURNACE
FROM ORE SCREENING OPERATION
COKE BREEZE
ORE FINES
EXHAUST GASES
GAS CLEANING
SINTER MACHINE
BREAKER & HOT SCREEN
COOLER
SINTER PLANT
MILL SCALE
SINTER
PELLETS
LUMP ORE
SCRAP
COLD SCREEN
SCREEN
SCREEN
PELLET PILE
PELLETS
PELLETIZING (AT MINE SITE)
RR CAR
(OR SHIP)
DIRECT REDUCTION
TO STEEL FURNACES
LUMP ORE PILE
LUMP ORE (FROM MINE)
RR CAR
(OR SHIP)
COKE
SCRAP
SCRAP PILE
SCRAP
RR CAR
(OR SHIP OR TRUCK)
BLAST FURNACE
HOT AIR
STOVES
COKE PILE
FINISHED COKE
COKE BREEZE
IRON
HOT METAL TRANSFER
LADLE (OR MIXER)
IRON DESULPHURIZATION
PRIMARY GAS CLEANING
EXHAUST GASES AND DUST
OPEN HEARTH FURNACE
GAS CLEANING
BASIC OXYGEN FURNACE (ALTERNATE)
ELECTRIC-ARC FURNACE (ALTERNATE)
GAS CLEANING
STEEL FURNACES
CONTINUOUS CASTING
BILLETS, SLABS, AND ROUNDS
CASTING
TEEMING
INGOTS
SOAKING PIT
BLOOM, BILLET, AND SLAB ROLLING
SCARFING
REHEAT FURNACE
FINISHED PRODUCT PROCESSING
EXHAUST GASES AND DUST
SECONDARY GAS CLEANING
CLEANED BLAST FURNACE GAS TO BE USED AS FUEL
DUST (TO SINTER OR BLAST FURNACE)
BY-PRODUCT RECOVERY
COKE OVEN GAS TO BE USED AS FUEL
COMBUSTION STACK EMISSIONS
COKING
SCREEN
COKE FINES TO SINTER PLANT
QUENCHING TOWER
COKE OVEN
COAL PREHEATER
COAL PILE
COAL
RR CAR

Figure 4.6-1 General flow diagram for the iron and steel industry.[1]

4.6.1.2 Coke Ovens Coke is used in iron foundries and in steel mill blast furnaces. Coke is manufactured by heating bituminous coal in the absence of oxygen to drive off the volatile compounds. Coal is pulverized, then heated for 15 to 18 hours to produce blast furnace coke or 25 to 30 hours for foundry coke. The volatile components of the coal are driven off, leaving behind the high-carbon content coke in the oven. At the end of the heating cycle, the doors are opened on both sides of the coke oven, and the incandescent coke is pushed from the oven into a special hopper rail car by a mechanical ram. The hot coke in the quench car is then moved to a quench tower where the hot coke is cooled by the addition of large quantities of water. The coke is then discharged from the quench car, allowed to drain and cool, and then crushed and screened. The coke can then be used as a fuel and a reducing agent for the production of iron.[2]

4.6.1.3 Sinter Plant The sintering process converts materials such as fine ore concentrates, blast furnace flue dust, mill scale, turnings, coke fines, limestones fines, and miscellaneous fines into an agglomerated product that is suitable for blast furnace feed material. Fine iron ore particulate matter, whether in natural or in concentrated ores, must be agglomerated to a size and strength suitable for blast furnace charging. This is done by depositing the mixture on a sinter machine traveling grate through which combustion air is drawn into a windbox. The mixture is ignited by natural gas or fuel oil and burns to form a fused mass which is fed to a cooler, crushed, and then screened in preparation for charging into a blast furnace.[3]

4.6.1.4 Blast Furnaces Iron is produced in the blast furnace from a charge of iron ore, coke, and limestone. The iron ore descends down the furnace and is reduced and melted by the countercurrent flow of hot gases produced by the partial combustion of coke. Hot metal is removed from the bottom of the blast furnace and transferred to steel-making operations.

4.6.1.5 Steel Furnaces There are three types of steel making furnaces in use today. These are the open hearth (OH) furnace, the basic oxygen furnace (BOF), and the electric arc furnace (EAF). Most of the nation's steel is made in BOFs and EAFs. The OH furnace takes the longest time (between 8 and 12 hours) to produce a batch of finished steel. The BOF uses about 70 percent hot metal and 30 percent scrap and requires a cycle taking less than an hour to produce a batch of finished steel. In the BOF, a water-cooled lance is used to supply pure oxygen to a mixture of hot metal, steel scrap, and flux materials. The oxygen reacts exothermically with the carbon in the metal, producing the heat required for melting. In the EAF, carbon electrodes supply the heat necessary for melting the metal. Flux is added after the metal is molten. Molten metal is tapped from the steel furnace and poured into ingot molds. The EAF can melt up to 100 percent scrap metal.

4.6.1.6 Finishing. Steel ingots are heated in a soaking pit furnace to prepare them for hot working (rolling). After the ingots are rolled into billets, blooms, or slabs, they are cooled and inspected. Surface defects are removed by grinding, chipping, peeling, or scarfing.

4.6.2 Geographic Distribution

Iron and steel producing plants are located in forty states. Most of the plants, however, are located in the area east of the Mississippi River and north of the Ohio River. The states with the greatest concentration of steelmaking capacity are Illinois, Indiana, Ohio, and Pennsylvania. Figure 4.6-2, for example, shows the locations of the basic oxygen furnace process plants in the United States. These plants include most of the integrated steel plants in the United States.

4.6.3 Emission Control Techniques

4.6.3.1 Coke Ovens. The control of particulate and cadmium emissions from charging operations can be accomplished by stage charging, sequential charging, or wet scrubber control systems. Stage charging is a procedure for charging coal into coke ovens in such a manner the passageway to the off gas collection flues remains open. The gases and particulate emissions generated in the oven are drawn into the collection flue by steam aspiration (or aspiration using a liquor) and exhausted by the regular gas handling equipment into the by-product recovery plant. Sequential charging differs from stage charging only in that the oven is charged more rapidly than in stage charging, thus producing gases and particulate matter at a faster rate. Scrubber control systems utilize a wet scrubber mounted on the larry car to control emissions captured by hoods at the charging ports.

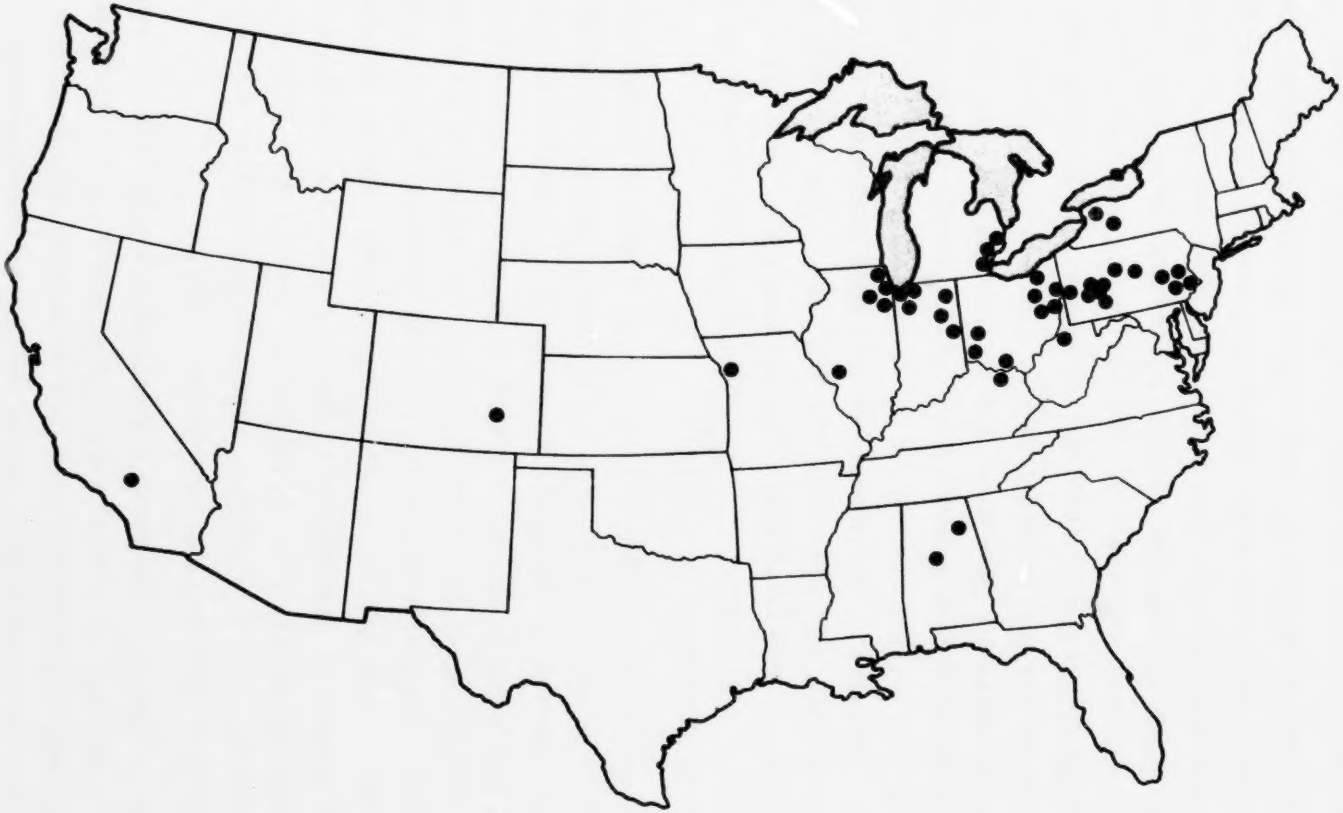


Figure 4.6-2 Location of basic oxygen furnaces in the U.S.[4]

Control technology for the control of emissions from charging lids and standpipes involves proper maintenance and replacement of oven closure devices, sealing of lids and standpipes, inspection, and resealing.

Three methods can be used to control coke pushing emissions. These are the use of a one spot (or enclosed) quench car, the installation of a full-length shed over the coke exit side of the oven, and traveling hoods. The one-spot quench car provides exhaust gas hooding during the pushing of the coke from the oven into the car. The collected gases and particulate matter are drawn from the enclosure into an exhaust gas cleaning car which employs a scrubber for particulate removal. The full-length shed collects and contains the emissions generated from the pushing operation while the air is drawn from the shed into a particulate control device such as a scrubber. The traveling hood involves the use of a mobile hood (attached to the quench car) which is connected to an overhead exhaust main that feeds the collected gases and particulate matter into control equipment. The emissions generated from the pushing of uncoked or green coal are capable of overloading most control systems. Thus, it is critical that the coal be properly coked to preclude the handling of uncoked coal.[5]

The control of quench tower particulate emissions is accomplished by installing baffles which are designed to intercept particulate matter and water droplets carried in the quench tower updraft. Emissions can also be reduced if clean water instead of dirty water is used for quench water. During the coking process all of the off gases are ducted to the byproduct recovery plant. Since coke temperatures at the end of each cycle are between 900°C and 1100°C (1650-2000°F) essentially all of the cadmium is volatilizied into the off gases. In the byproduct plant the gases are treated to produce a pipeline quality gaseous fuel. Consequently there are no significant cadmium emissions. The only cadmium emissions are from coal dust escaping during charging. These emissions are trace amounts.

4.6.3.2 Sintering. Cyclones, electrostatic precipitators, baghouses, and scrubbers are used to control emissions from sintering. Baghouses and medium-energy wet scrubbers have been used to control emissions from the sinter plants. The plume opacity can be reduced to nearly zero percent using either of these controls

4.6.3.3 Blast Furnaces. Various types of control equipment are presently used to control particulate emissions from blast furnaces. Dry cyclones, wet scrubbers, and electrostatic precipitators are common. Essentially all of the cadmium is volatilized into the blast furnace gas.

Blast furnace gas is almost universally treated to produce a high purity, low heating value fuel. The only time even a trace amount of cadmium would be emitted would be from process upsets such as blast furnace slips that actuate the relief valve. This discharges uncontrolled particulates to the atmosphere. These upsets are infrequent. Consequently there are only trace cadmium emissions from blast furnaces.

4.6.3.4 Steel Furnaces The small size of the particulate matter emitted from open hearth furnaces necessitates the use of high-efficiency collection equipment such as venturi scrubbers and electrostatic precipitators. Baghouses have also been installed for particulate emission control but they require that the gases be precooled.

Venturi scrubbers and electrostatic precipitators are commonly used to control particulate emissions from basic oxygen furnaces. The emissions are usually routed through either an open or closed hood.

Fabric filters are the most commonly used devices for cleaning electric arc furnace gases, although venturi scrubbers and electrostatic precipitators are also used. The use of a baghouse on an electric arc furnace necessitates precooling of gases to protect the bags.

4.6.4 Emissions

The quantity of cadmium introduced to the I&S industry each year is estimated and presented in this section because the amount of cadmium entering the industry processes each year determines the amount of airborne cadmium emitted annually. All of the cadmium introduced to the industry processes each year is assumed to be volatilized by the high operating temperatures and emitted as particulate. The quantities of particulate emissions and cadmium emissions from steelmaking processes and iron foundries are also presented in this section.

Table 4.6-1 presents the quantity of cadmium entering the iron and steel industry each year. A total of 340.2 Mg (376 tons) of cadmium enter the I&S industry in No. 2 scrap, coal, and iron ore. Number 2 scrap has an average cadmium content of 45 ppm[6], coal has an average cadmium content of 0.32 ppm[7], and iron ore has an average cadmium content of 0.2 ppm.[8]

Table 4.6-2 presents a summary of estimated airborne particulate and cadmium emissions from the I&S industry for individual steel processes and iron foundries. Annual cadmium entering the industry is estimated to be 340 Mg (376 tons). Annual controlled cadmium emissions are estimated to be 12.6 Mg (13.9 tons). The cadmium collection efficiency is assumed to be the same as the particulate collection efficiency for each process.

4.6.4.1 Coke Ovens Annual uncontrolled cadmium emissions from coke ovens are estimated to be 22 Mg (24 tons). Annual controlled cadmium emissions from coke ovens are estimated to be trace amounts (See section 4.6.3.1).

4.6.4.2 Sinter Machines Annual uncontrolled cadmium emissions from sinter machines are estimated to be 23 Mg (25 tons). Annual controlled cadmium emissions from sinter machines are estimated to be 2.0 Mg (2.2 tons).

4.6.4.3 Blast Furnaces Annual uncontrolled emissions of cadmium from blast furnaces are estimated to be 18.7 Mg (20.8 tons). Controlled emissions are trace amounts (see section 4.6.3.3).

4.6.4.4 Basic Oxygen Furnaces Annual uncontrolled emissions of cadmium from BOFs are estimated to be 114 Mg (126 tons). Annual controlled emissions of cadmium from BOFs are estimated to be 4.6 Mg (5.1 tons).

4.6.4.5 Electric Arc Furnaces Annual national uncontrolled cadmium emissions from electric arc furnaces are estimated to be 106 Mg (117 tons). Annual national controlled cadmium emissions from electric arc furnaces are estimated to be 3.2 Mg (3.5 tons).

4.6.4.6 Open Hearth Furnaces Annual uncontrolled emissions of cadmium from open hearth furnaces are estimated to be 54 Mg (59 tons). Annual controlled emissions of cadmium from open hearth furnaces are estimated to be 2.7 Mg (3.0 tons).

TABLE 4.6-1 QUANTITY OF CADMIUM ENTERING THE IRON AND STEEL INDUSTRY

Process[a]	Material containing cadmium	Quantity of input material, 10^6 Mg/yr (10^6 tpy)	Cadmium concentration of input material, ppm	Quantity of cadmium input, Mg/yr (tpy)
BOF	No. 2 scrap	2.54 (2.8)[b]	45	114 (126)
EAF	No. 2 scrap	2.36 (2.6)[b]	45	106 (117)
OH	No. 2 scrap	1.2 (1.3)[b]	45	54 (59)
Sintering	Miscellaneous[c]	33 (36.4)	0.68	22 (25)
BF[d]	Ore/pellets	90.7 (100)	0.2	18 (20)
	Flux	10 (11.1)	0.07	0.7 (0.8)
Coking	Coal	69 (76)	0.32	22 (24)
Specialty shops	None (assumed)	-- --	--	None (assumed)
Foundries[e]	Ores	18.1 (20)	0.2	3.6 (4.0)
	Flux	1.8 (2)	0.07	0.1 (0.1)
TOTAL				340.4 (375.9)

[a] BOF = Basic oxygen furnace; EAF = Electric arc furnace; OH = Open hearth furnace; BF = Blast furnace.

[b] Scrap consumption figures published by the AISI, 1979.

[c] Sintering material consists of several materials, and may vary greatly from plant to plant.

[d] The 18.7 Mg (20.8 tons) of cadmium will be removed by gas-cleaning equipment when the off-gases from the BF are treated for use as fuel.

[e] Foundries reported no use of No. 2 scrap in their EAFs.

TABLE 4.6-2a SUMMARY OF ESTIMATED AIRBORNE PARTICULATE AND CADMIUM EMISSIONS FROM THE IRON AND STEEL INDUSTRY

Process[a]	Particulate (Mg/yr) Uncontrolled[b]	Particulate (Mg/yr) Existing control[c]	Implied collection efficiency (%)	Cadmium (Mg/yr) Uncontrolled[d]	Cadmium (Mg/yr) Existing control[c]
BOF	1,205,780	45,740	96	114	4.6
EAF	1,773,600	64,480	97	106	3.2
OH	42,000	1,920	95	54	2.7
Sintering	246,670	21,100	91	22	2.0
BF[f]	29,440	29,440	(f)	18.7	Tr
Coking[g]	127,590	73,530	(g)	22	Tr
Miscellaneous[h]	134,750	100,940	25	Tr	Tr
Foundries	494,380	10,460	97.9	3.7	0.08
TOTAL	4,054,210	347,610		340.4	12.58

[a] BOF = Basic oxygen furnace; EAF = Electric arc furnace; OH = Open hearth furnace; BF = Blast furnace.

[b] Reference 1.

[c] Reference 10.

[d] Values explained in Table 4.6-1.

[e] Determined by uncontrolled cadmium emissions x $\frac{100 - \text{efficiency}}{100}$.

[f] Uncontrolled particulate emissions for BFs consider off-gases being recirculated. All cadmium is assumed to be removed by the 99.99 percent efficient gas cleaning systems. See Section 4.6.3.3. The estimated particulates do not contain significant amounts of cadmium.

[g] Most particulate emissions result after the coking cycle volatizes the cadmium. Cadmium collection efficiency is based on assumed treatment of cadmium in a typical by-products plant. See Section 4.6.3.1.

[h] Miscellaneous sources are listed in Table 4.6-3.

Tr = Trace

TABLE 4.6-2b SUMMARY OF ESTIMATED AIRBORNE PARTICULATE AND CADMIUM EMISSIONS FROM THE IRON AND STEEL INDUSTRY

Process[a]	Particulate (tons/yr)		Implied collection efficiency (%)	Cadmium (tons/yr)	
	Uncontrolled[b]	Existing control[c]		Uncontrolled[d]	Existing control[e]
BOF	1,329,153	50,420	96	126	5.0
EAF	1,955,066	71,076	97	117	3.5
OH	46,297	2,114	95	59	3.0
Sintering	271,910	23,264	91	25	2.3
BF[f]	32,452	32,452	(f)	20.8	Tr
Coking[g]	140,641	81,054	(g)	24	Tr
Miscellaneous[h]	148,538	111,264	26	Tr	Tr
Foundries	544,960	11,526	97.9	4.1	0.09
TOTAL	4,469,017	383,170		375.9	13.89

[a] BOF = Basic oxygen furnace; EAF = Electric arc furnace; OH = Open hearth furnace; BF = Blast furnace.

[b] Reference 9.

[c] Reference 10.

[d] Values explained in Table 4.6-1.

[e] Determine by uncontrolled cadmium emissions x implied collection efficiency, except for BF and coking.

[f] Uncontrolled particulate emissions for BFs consider off-gases being recirculated. All cadmium is assumed to be removed by the 99.99 percent efficient gas cleaning systems. See Section 4.6.3.3. The estimated particulates do not contain significant amounts of cadmium.

[g] Most particulate emissions result after the 1600-2000°F coking cycle with cadmium already volatized. Cadmium collection efficiency is based on assumed treatment of cadmium in a typical by-products plant. See Section 4.6.3.1.

[h] Miscellaneous sources are listed in Table 4.6-3.

Tr = Trace

4.6.4.7 Miscellaneous Sources. Miscellaneous sources include finishing operations, ore screening, open areas, roadways, and coal preparation. Only a trace of cadmium is estimated to be emitted by all miscellaneous sources.

4.6.4.8 Iron Foundries. Annual uncontrolled emissions of cadmium from iron foundries are estimated to be 3.7 Mg (4.1 tons). Annual controlled emissions of cadmium from iron foundries are estimated to be 0.08 Mg (0.09 ton).

4.6.5 Model Plants

In order to estimate the hourly and annual cadmium emissions expected from individual mills and to provide information which is useful for future dispersion analyses, model steel mills are presented in this section. The model steel mills (model plants) consists of several processes which are presented separately as model facilities. The model facilities are a coke battery, a sinter plant, a blast furnace shop, a BOF shop, a EAF shop, an OH shop, and a miscellaneous sources listing.

Three types of model plants are presented: (1) an integrated steel plant; (2) a non-integrated steel plant; and (3) a small-to-medium (mini-medi) steel plant. An integrated steel plant is defined as a steel mill which produces coke, iron, and steel. A non-integrated steel mill is defined as a mill that produces either coke and iron and over 907,000 Mg (one million tons) of steel per year. A mini-medi mill is a plant that produces less than one million tons of steel per year.

Model plants were not developed for specialty steel plants or iron foundries because the emissions of cadmium from these types of plants are expected to be very low.

4.6.5.1 Model Facilities

4.6.5.1.1 Coke Facility The model coke facility is illustrated in Figure 4.6-3. The model facility consists of four coke batteries producing a total of 1.45 x 10^6 Mg (1.6 x 10^6 tons) of coke each year.

4.6.5.1.2 Sinter Facility The model sinter facility is illustrated and presented in Figure 4.6-4. The model facility consists of one sinter strand producing 1.03 x 10^6 Mg (1.13 x 10^6 tons) of sinter material per year.

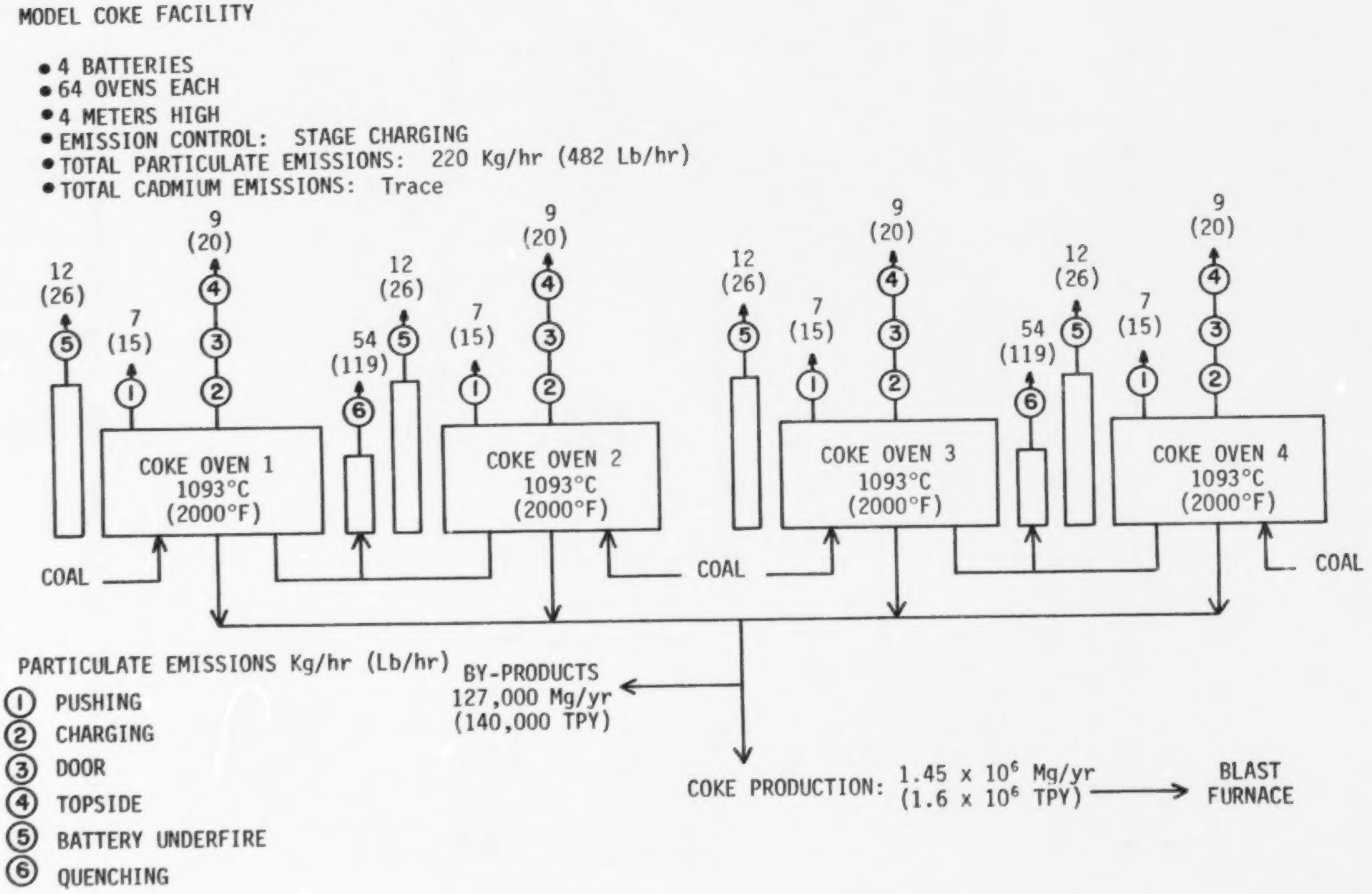

MODEL COKE FACILITY
• 4 BATTERIES
• 64 OVENS EACH
• 4 METERS HIGH
• EMISSION CONTROL: STAGE CHARGING
• TOTAL PARTICULATE EMISSIONS: 220 Kg/hr (482 Lb/hr)
• TOTAL CADMIUM EMISSIONS: Trace
12 (26)
7 (15)
9 (20)
54 (119)
COKE OVEN 1 1093°C (2000°F)
COKE OVEN 2 1093°C (2000°F)
COKE OVEN 3 1093°C (2000°F)
COKE OVEN 4 1093°C (2000°F)
COAL
PARTICULATE EMISSIONS Kg/hr (Lb/hr)
① PUSHING
② CHARGING
③ DOOR
④ TOPSIDE
⑤ BATTERY UNDERFIRE
⑥ QUENCHING
BY-PRODUCTS 127,000 Mg/yr (140,000 TPY)
COKE PRODUCTION: 1.45 x 10⁶ Mg/yr (1.6 x 10⁶ TPY)
BLAST FURNACE

Figure 4.6-3. Model coke plant for an integrated iron and steel mill.

MODEL SINTER FACILITY

- 1 STRAND
- EMISSION CONTROL: ELECTROSTATIC PRECIPITATORS (OPERATING POORLY)
- TOTAL PARTICULATE EMISSIONS: 75 Kg/hr (166 Lb/hr)
- TOTAL CADMIUM EMISSIONS: 0.009 Kg/hr (0.02 Lb/hr)

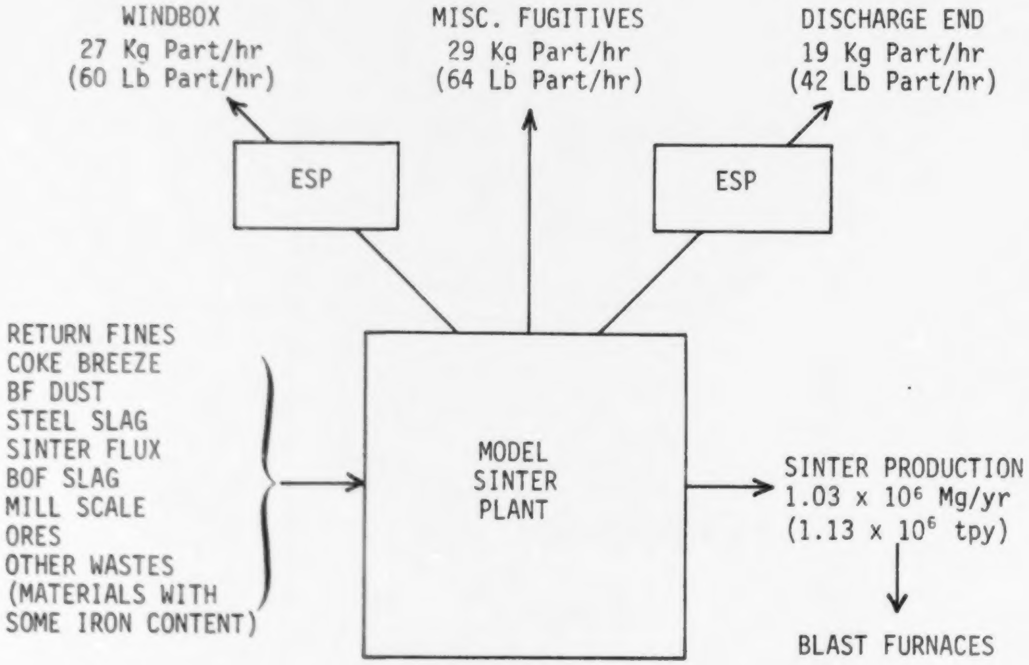

WINDBOX
27 Kg Part/hr
(60 Lb Part/hr)
MISC. FUGITIVES
29 Kg Part/hr
(64 Lb Part/hr)
DISCHARGE END
19 Kg Part/hr
(42 Lb Part/hr)
ESP
ESP
RETURN FINES
COKE BREEZE
BF DUST
STEEL SLAG
SINTER FLUX
BOF SLAG
MILL SCALE
ORES
OTHER WASTES
(MATERIALS WITH
SOME IRON CONTENT)
MODEL
SINTER
PLANT
SINTER PRODUCTION
1.03 x 10⁶ Mg/yr
(1.13 x 10⁶ tpy)
BLAST FURNACES

Figure 4.6-4 Model sinter plant for an integrated steel mill.

4.6.5.1.3 Blast Furnace Shop The model blast furnace shop is illustrated in Figure 4.6-5. The model BF shop consists of three blast furnaces, each with an associated casthouse. The blast furnaces together produce a total of 2.4×10^6 Mg (2.6×10^6 tons) of iron per year.

4.6.5.1.4 Basic Oxygen Furnace Shop The model BOF shop is illustrated in Figure 4.6-6. The model shop consists of two BOFs producing a total of 2.27×10^6 Mg (2.5×10^6 tons) of steel per year. The BOFs have the capacity to produce 272 Mg (300 tons) of steel at a time. The emission control device is an electrostatic precipitator.

4.6.5.1.5 Electric Arc Furnace Shop The model EAF shop is presented in Figure 4.6-7, and consists of three EAFs which produce 694,000 Mg (765,000 tons) of steel per year. Particulate emissions are controlled by a baghouse.

4.6.5.1.6 Open Hearth Furnace Shop The model OH furnace shop is presented in Figure 4.6-8, and consists of five OH furnaces producing 626,000 Mg (690,000 tons) of steel per year.

4.6.5.1.7 Miscellaneous Sources A listing of miscellaneous particulate emission sources is presented in Table 4.6-3. The miscellaneous sources include finishing operations, material piles, open areas, and roads.

4.6.5.2 Model Plants

4.6.5.2.1 Integrated Steel Mill The model integrated steel mill is illustrated in Figure 4.6-9. The model mill consists of one model coke facility, a model sinter facility, a model blast furnace shop, a model BOF shop, a model EAF shop, a model OH furnace shop, and a miscellaneous sources listing.

4.6.5.2.2 Non-Integrated Steel Mill The model non-integrated steel mill is illustrated in Figure 4.6-10. The model mill brings in coke from outside the mill rather than manufacturing coke at the mill. The model non-integrated steel plant consists of two blast furnaces, a model BOF shop, a model EAF shop, and a miscellaneous sources listing.

MODEL BLAST FURNACE SHOP

- 3 BLAST FURNACES
- 8 CASTS PER DAY EACH
- NO CASTHOUSE EMISSION CONTROL
- TOTAL PARTICULATE EMISSIONS: 90 Kg/hr (195 Lb/hr)
- TOTAL CADMIUM EMISSIONS: Trace
- PRIMARY OFF-GASES RECYCLED: CLEANED BY A DUST COLLECTOR AND TWO SCRUBBERS

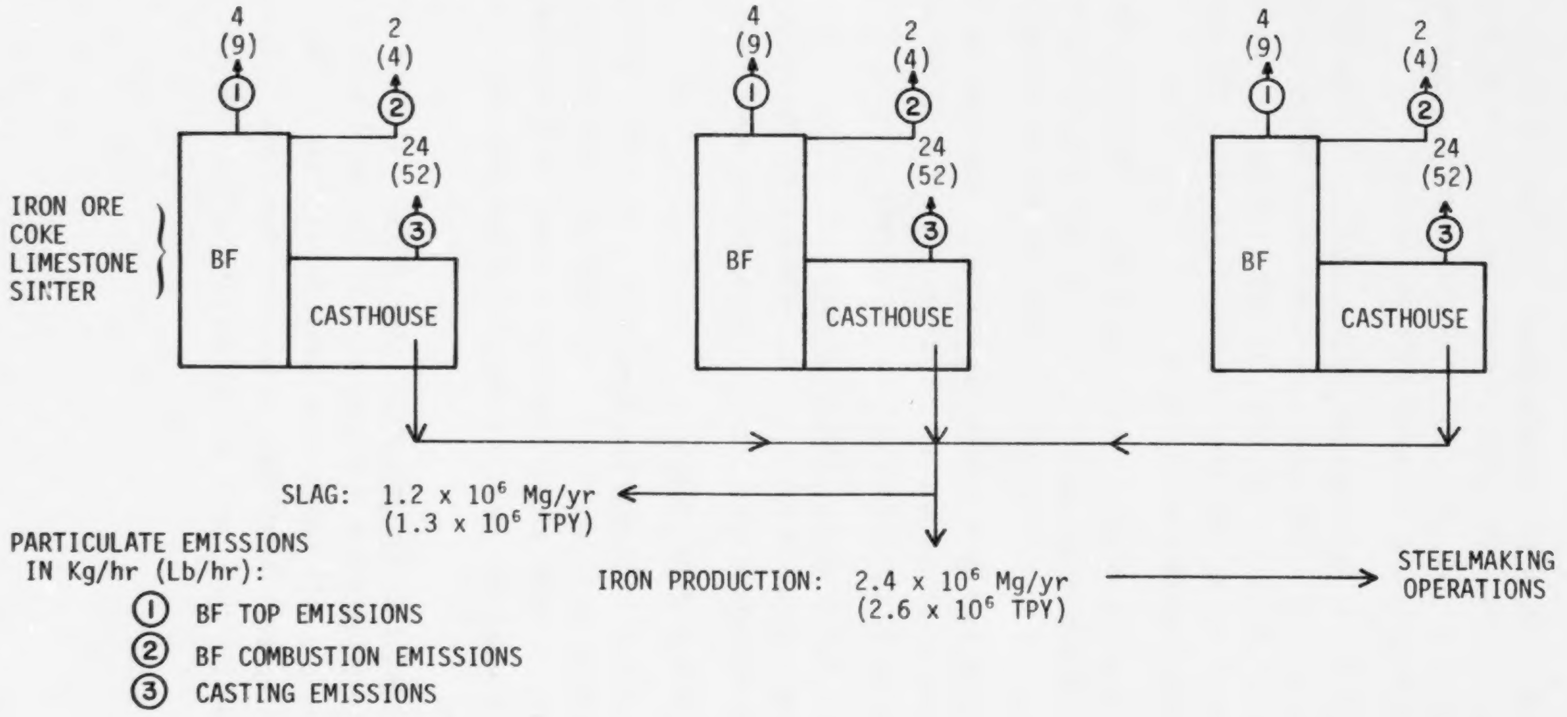

IRON ORE
COKE
LIMESTONE
SINTER
BF
CASTHOUSE
4 (9)
2 (4)
24 (52)
①
②
③
SLAG: 1.2 x 10⁶ Mg/yr (1.3 x 10⁶ TPY)
IRON PRODUCTION: 2.4 x 10⁶ Mg/yr (2.6 x 10⁶ TPY)
STEELMAKING OPERATIONS
PARTICULATE EMISSIONS IN Kg/hr (Lb/hr):
① BF TOP EMISSIONS
② BF COMBUSTION EMISSIONS
③ CASTING EMISSIONS

Figure 4.6-5 Model blast furnace plant for an integrated steel mill.

MODEL BOF-SHOP

- PRODUCTION: 2.27×10^6 Mg/yr (2.5×10^6 TPY)
- TOP BLOWN-OPEN HOOD DESIGN
- EVACUATION OF ONLY ONE FURNACE AT A TIME
- DURATION OF ONE HEAT:
  45 MIN. WITH O BLOW OF 20 MIN.
- 22 HEATS/DAY
- TOTAL PARTICULATE EMISSIONS: 126 Kg/hr (276 Lb/hr)
- TOTAL CADMIUM EMISSIONS: 0.014 Kg/hr (0.03 Lb/hr)

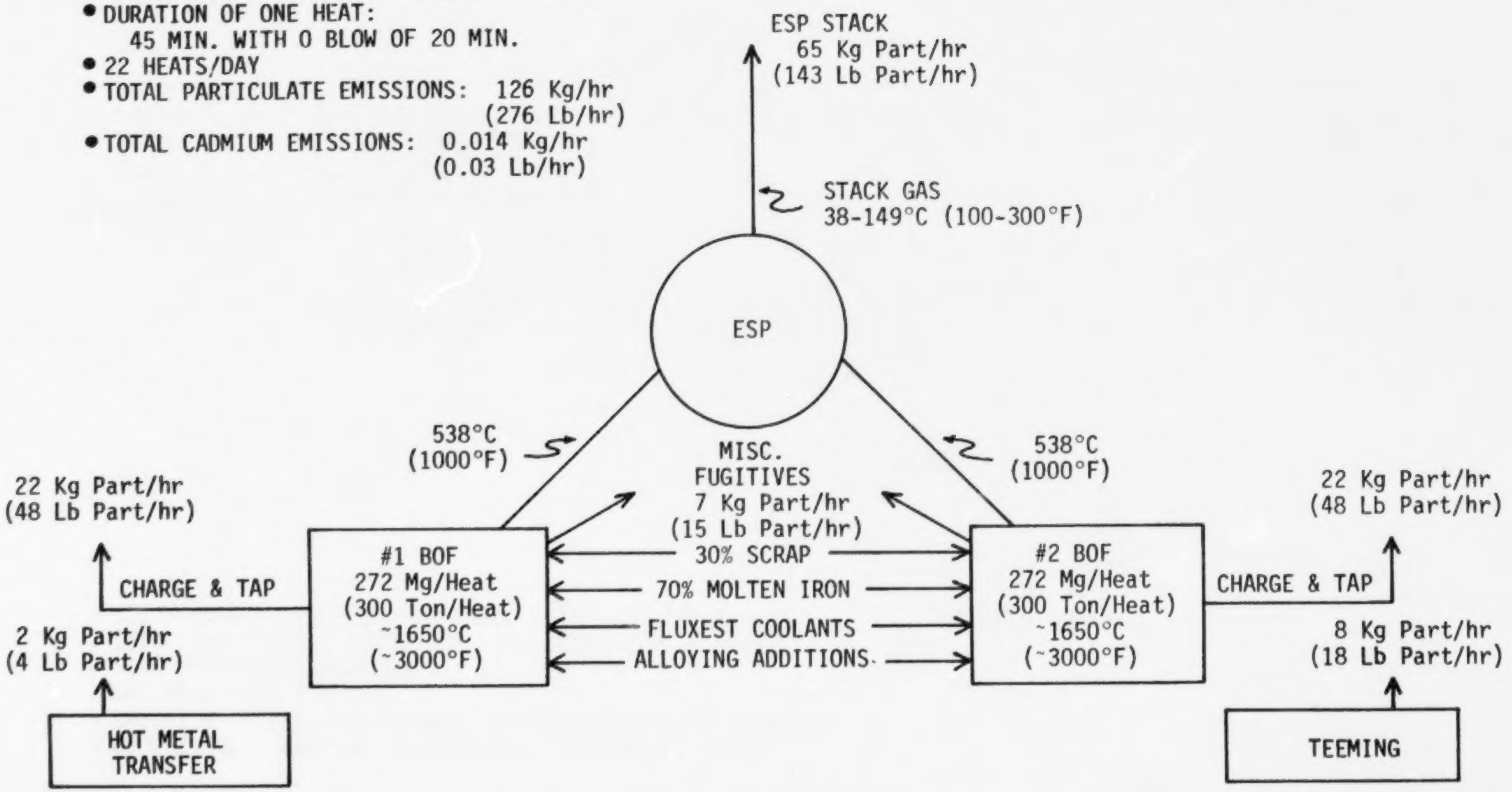

ESP STACK
65 Kg Part/hr
(143 Lb Part/hr)
STACK GAS
38-149°C (100-300°F)
ESP
538°C
(1000°F)
538°C
(1000°F)
MISC.
FUGITIVES
7 Kg Part/hr
(15 Lb Part/hr)
30% SCRAP
70% MOLTEN IRON
FLUXEST COOLANTS
ALLOYING ADDITIONS
#1 BOF
272 Mg/Heat
(300 Ton/Heat)
~1650°C
(~3000°F)
#2 BOF
272 Mg/Heat
(300 Ton/Heat)
~1650°C
(~3000°F)
22 Kg Part/hr
(48 Lb Part/hr)
CHARGE & TAP
2 Kg Part/hr
(4 Lb Part/hr)
HOT METAL TRANSFER
22 Kg Part/hr
(48 Lb Part/hr)
CHARGE & TAP
8 Kg Part/hr
(18 Lb Part/hr)
TEEMING

Figure 4.6-6. Model basic oxygen furnace shop for an integrated steel mill.

MODEL EAF SHOP

- PRODUCTION: 694,000 Mg Steel/Yr (765,000 Tons/Yr)
- EMISSION COLLECTION SYSTEM: CANOPY HOOD, OVER FURNACES
- ONE HEAT LAST 4 HOURS
- FIVE HEATS/DAY/FURNACE
- TOTAL PARTICULATE EMISSIONS: 47 Kg/hr (104 Lb/hr)
- TOTAL CADMIUM EMISSIONS: 0.005 Kg/hr (0.01 Lb/hr)

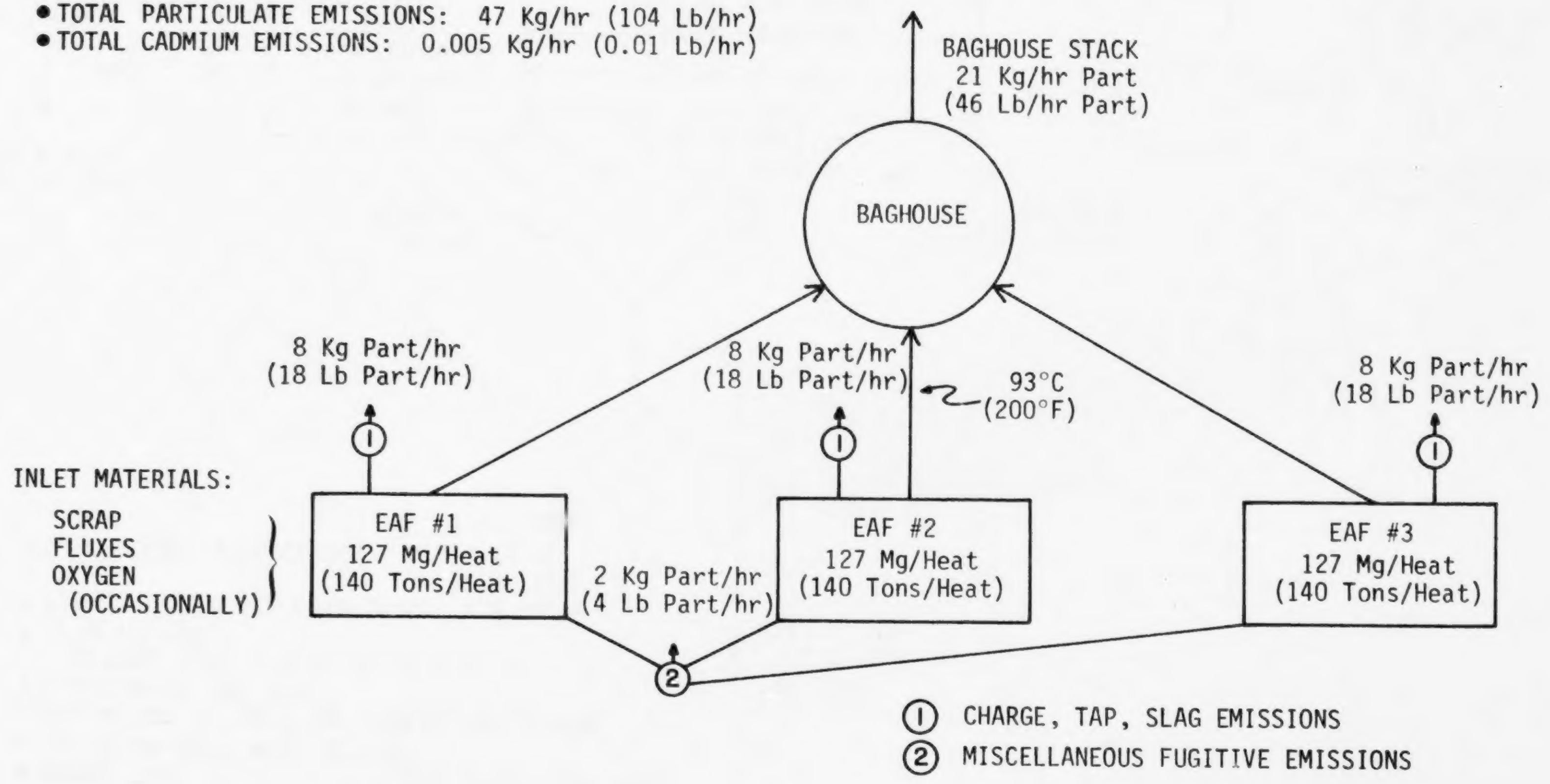

BAGHOUSE STACK
21 Kg/hr Part
(46 Lb/hr Part)
BAGHOUSE
8 Kg Part/hr
(18 Lb Part/hr)
8 Kg Part/hr
(18 Lb Part/hr)
93°C
(200°F)
8 Kg Part/hr
(18 Lb Part/hr)
①
①
①
INLET MATERIALS:
SCRAP
FLUXES
OXYGEN
(OCCASIONALLY)
EAF #1
127 Mg/Heat
(140 Tons/Heat)
2 Kg Part/hr
(4 Lb Part/hr)
EAF #2
127 Mg/Heat
(140 Tons/Heat)
EAF #3
127 Mg/Heat
(140 Tons/Heat)
②
① CHARGE, TAP, SLAG EMISSIONS
② MISCELLANEOUS FUGITIVE EMISSIONS

Figure 4.6-7. Model electric arc furnace shop in an integrated steel mill.

MODEL OPEN HEARTH FURANACE SHOP

- PRODUCTION: 625,950 Mg/yr (690,000 TPY)
- TAP TO TAP TIME: 9 HOURS
- TOTAL PARTICULATE EMISSIONS: 31.3 Kg/hr (69 Lb/hr)
- TOTAL CADMIUM EMISSIONS: 0.045 Kg/hr (0.1 Lb/hr)

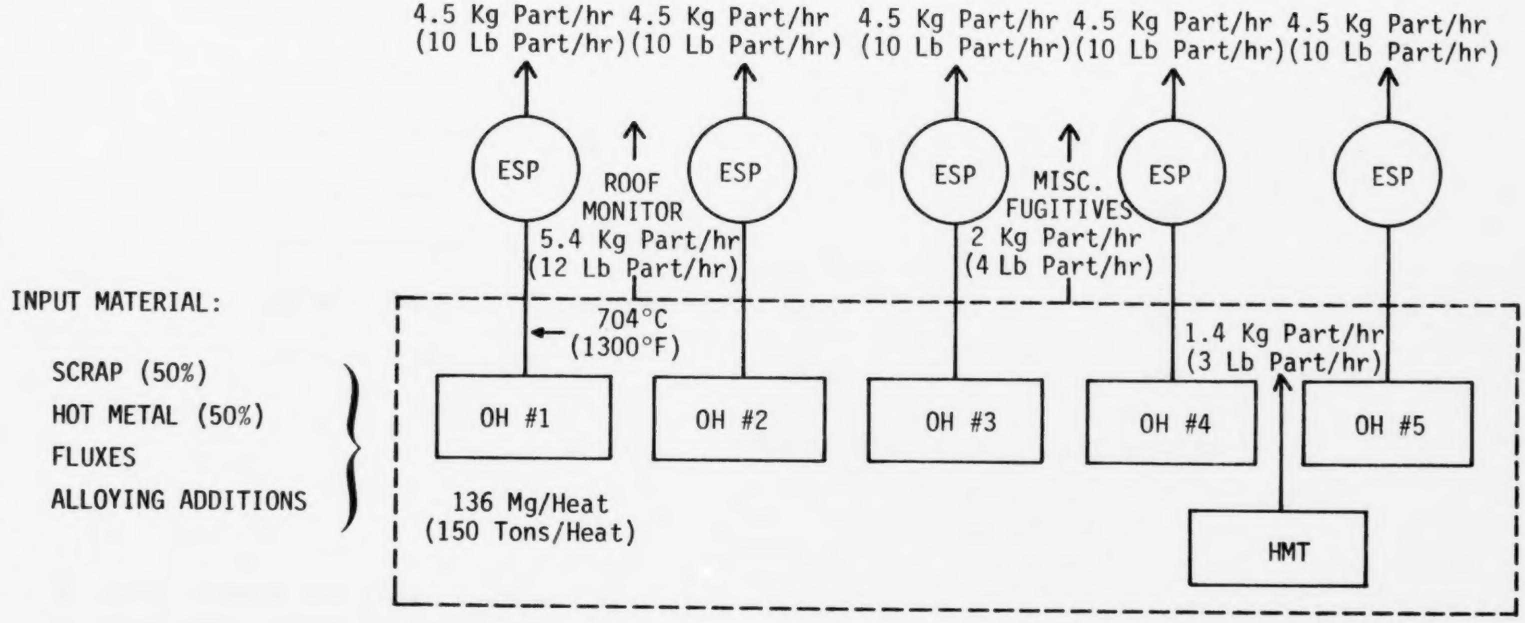

4.5 Kg Part/hr (10 Lb Part/hr)
4.5 Kg Part/hr (10 Lb Part/hr)
4.5 Kg Part/hr (10 Lb Part/hr)
4.5 Kg Part/hr (10 Lb Part/hr)
4.5 Kg Part/hr (10 Lb Part/hr)
ESP
ROOF MONITOR
ESP
ESP
MISC. FUGITIVES
ESP
ESP
5.4 Kg Part/hr (12 Lb Part/hr)
2 Kg Part/hr (4 Lb Part/hr)
INPUT MATERIAL:
SCRAP (50%)
HOT METAL (50%)
FLUXES
ALLOYING ADDITIONS
704°C (1300°F)
1.4 Kg Part/hr (3 Lb Part/hr)
OH #1
OH #2
OH #3
OH #4
OH #5
136 Mg/Heat (150 Tons/Heat)
HMT

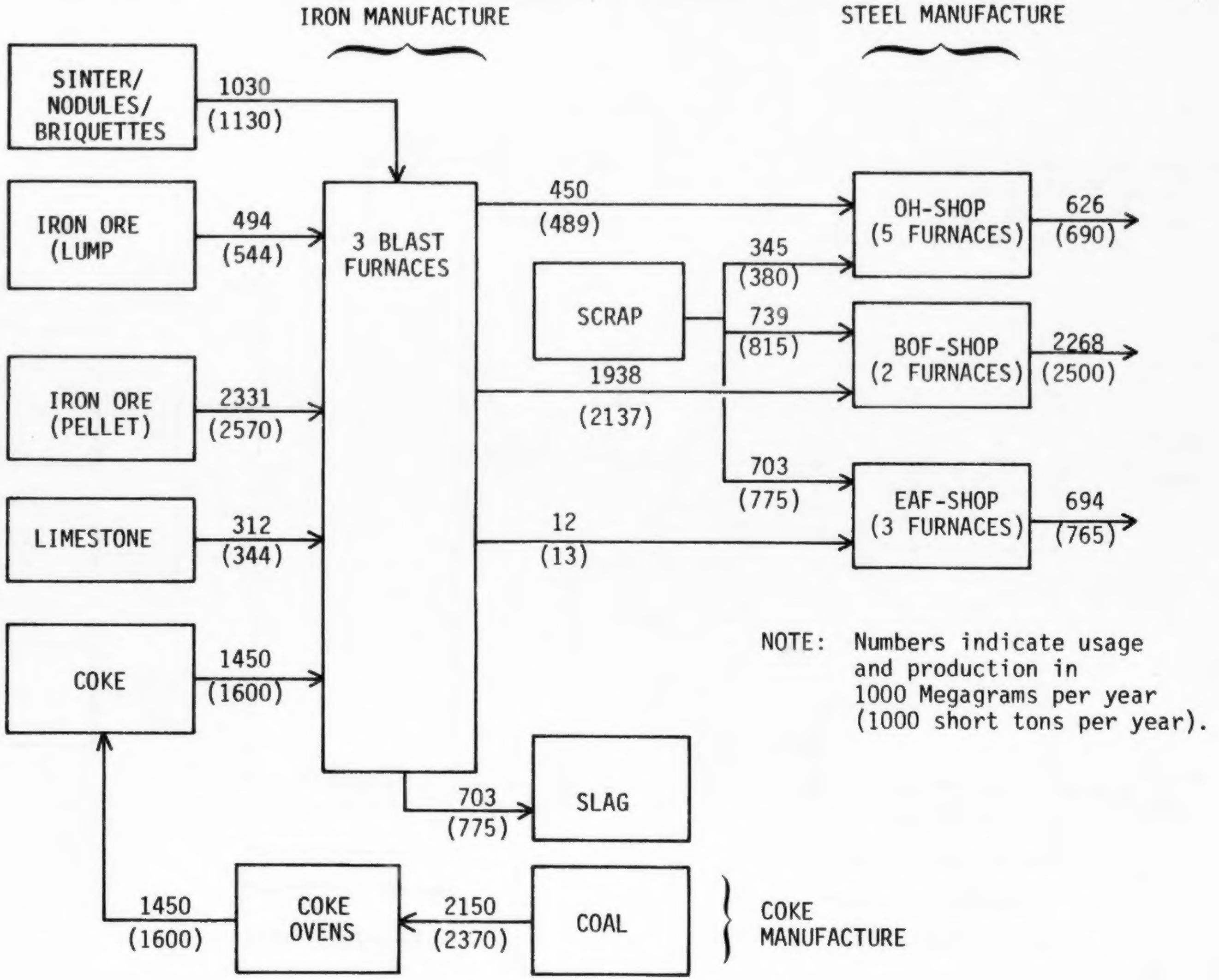
Figure 4.6-8. Model open hearth furnace shop in an integrated steel mill.

TABLE 4.6-3 MISCELLANEOUS SOURCES IN A MODEL INTEGRATED STEEL MILL

MODEL PLANT - MISCELLANEOUS SOURCES

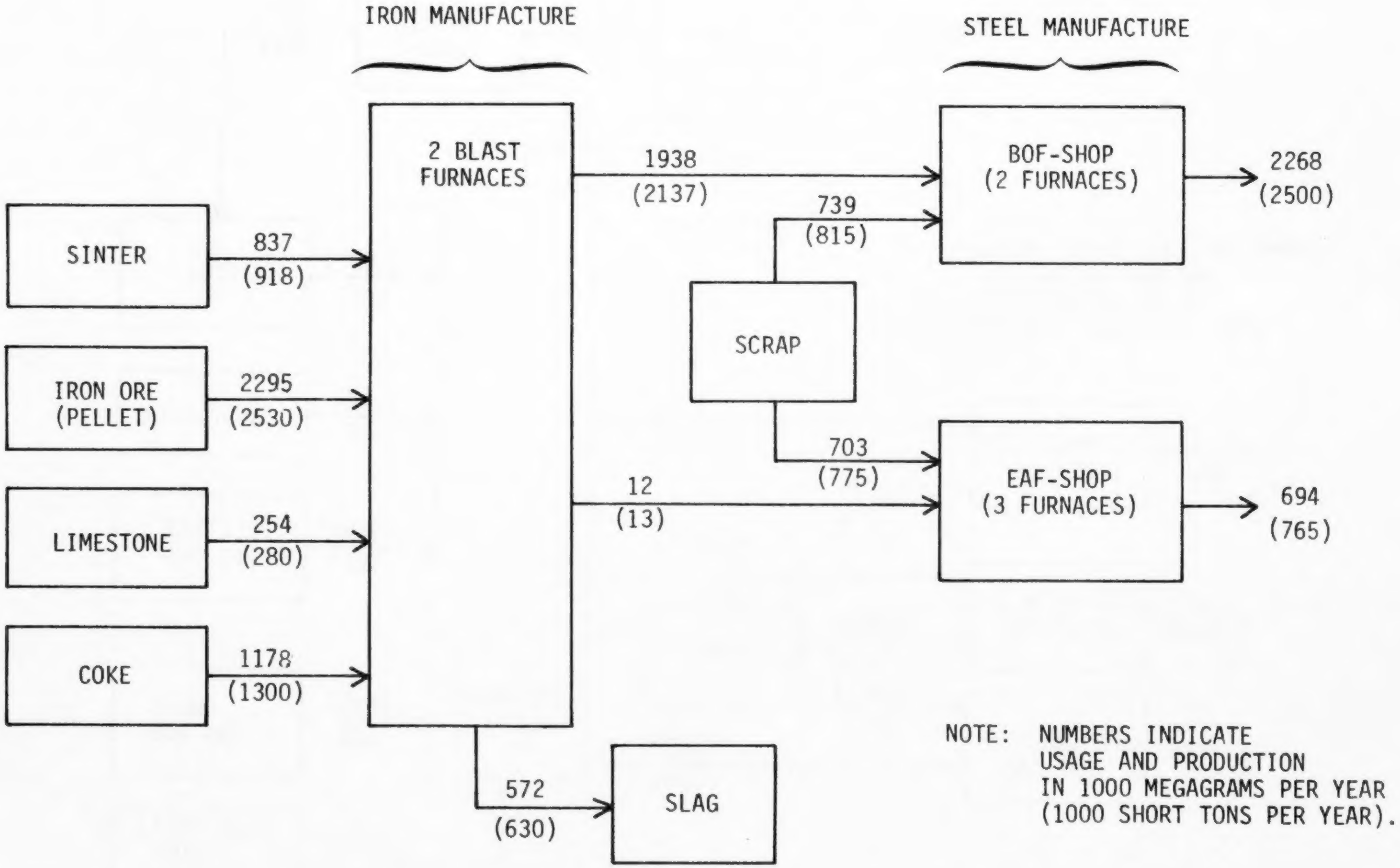
- TOTAL PARTICULATE EMISSIONS: 156 Kg/Hr (344 Lb/Hr)
- TOTAL CADMIUM EMISSIONS: Trace

	Kg Part/Hr	Lb Part/Hr
- Material Stock Piles	54.4	120
- Roadway Travel	53.5	118
- Coal Preparation	23.6	52
- Ore Screening	11.3	25
- Reheat Furnaces	5.9	13
- Open Areas	3.6	8
- Machine Scarfing	2.3	5
- Soaking Pits	1.4	3


IRON MANUFACTURE
STEEL MANUFACTURE
SINTER/ NODULES/ BRIQUETTES
1030
(1130)
IRON ORE (LUMP
494
(544)
IRON ORE (PELLET)
2331
(2570)
LIMESTONE
312
(344)
COKE
1450
(1600)
3 BLAST FURNACES
450
(489)
SCRAP
345
(380)
739
(815)
1938
(2137)
703
(775)
12
(13)
OH-SHOP (5 FURNACES)
626
(690)
BOF-SHOP (2 FURNACES)
2268
(2500)
EAF-SHOP (3 FURNACES)
694
(765)
703
(775)
SLAG
1450
(1600)
COKE OVENS
2150
(2370)
COAL
COKE MANUFACTURE

NOTE: Numbers indicate usage and production in 1000 Megagrams per year (1000 short tons per year).

Figure 4.6-9 Illustration of processes and material flows for a model integrated steel mill.


IRON MANUFACTURE
STEEL MANUFACTURE
SINTER
837
(918)
IRON ORE (PELLET)
2295
(2530)
LIMESTONE
254
(280)
COKE
1178
(1300)
2 BLAST FURNACES
572
(630)
SLAG
1938
(2137)
12
(13)
SCRAP
739
(815)
703
(775)
BOF-SHOP (2 FURNACES)
2268
(2500)
EAF-SHOP (3 FURNACES)
694
(765)

NOTE: NUMBERS INDICATE USAGE AND PRODUCTION IN 1000 MEGAGRAMS PER YEAR (1000 SHORT TONS PER YEAR).

Figure 4.6-10 Illustration of processes and material flows for a model non-integrated steel mill.

4.6.5.2.3 Mini-Medi Steel Mill The model mini-medi mill is illustrated in Figure 4.6-11. The model plant consists of two EAFs producing 199,580 Mg (220,000 tons) of steel per year with a continuous casting machine. Particulate emissions are controlled by a fabric filter.

4.6.5.3 Model Plant Emissions Cadmium and particulate emissions from model integrated steel mills, model non-integrated steel mills, and model mini-medi steel mills are summarized and presented in Table 4.6-4. The table presents uncontrolled and controlled particulate and cadmium emission rates for each process or shop where appropriate, and the total uncontrolled cadmium and particulate emissions for each model steel plant.

4.6.5.3.1 Integrated Steel Mill Uncontrolled cadmium emissions from the model integrated steel mill are estimated to be 1.64 Kg/hr (3.56 Lb/hr) or 14.35 Mg (15.61 tons) per year. Controlled cadmium emissions are estimated to be 0.073 Kg/hr (0.16 Lb/hr) or 0.63 Mg/yr (0.70 TPY).

4.6.5.3.2 Non-Integrated Steel Mill Uncontrolled cadmium emissions from the model non-integrated steel mill are estimated to be 0.58 Kg/hr (1.20 Lb/hr) or 5.05 Mg/yr (5.28 TPY). Controlled cadmium emissions from the model mill are estimated to be 0.019 Kg/hr (0.04 Lb/hr) or 0.16 Mg/yr (0.17 TPY).

4.6.5.3.3 Mini-Medi Steel Mill Uncontrolled cadmium emissions from the model mini-medi steel mill are estimated to be 0.10 Kg/hr (0.19 Lb/hr) or 0.85 Mg/yr (0.94 TPY). Controlled cadmium emissions from the model mill are estimated to be 0.003 Kg/hr (0.006 Lb/hr) or 0.023 Mg/yr (0.025 TPY).

4.6.6 Compliance Status*

This section discusses the compliance status of iron and steel industry with regard to current emission limitations. Emissions from new BOFs are regulated by a New Source Performance Standard. State emissions standards regulate emissions from other steel-making processes and iron foundries in terms of both opacity limitations and particulate emission limitations.

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

MODEL EAF SHOP FOR MINI-MEDI MILL

- STEEL PRODUCTION: 199,580 MG/YR (220,000 TPY)
- ONE HEAT LAST 3 HOURS
- TOTAL PARTICULATE EMISSIONS: 26.5 KG/HR (60 LB/HR)
- TOTAL CADMIUM EMISSIONS: 0.003 KG/HR (0.004 LB/HR)

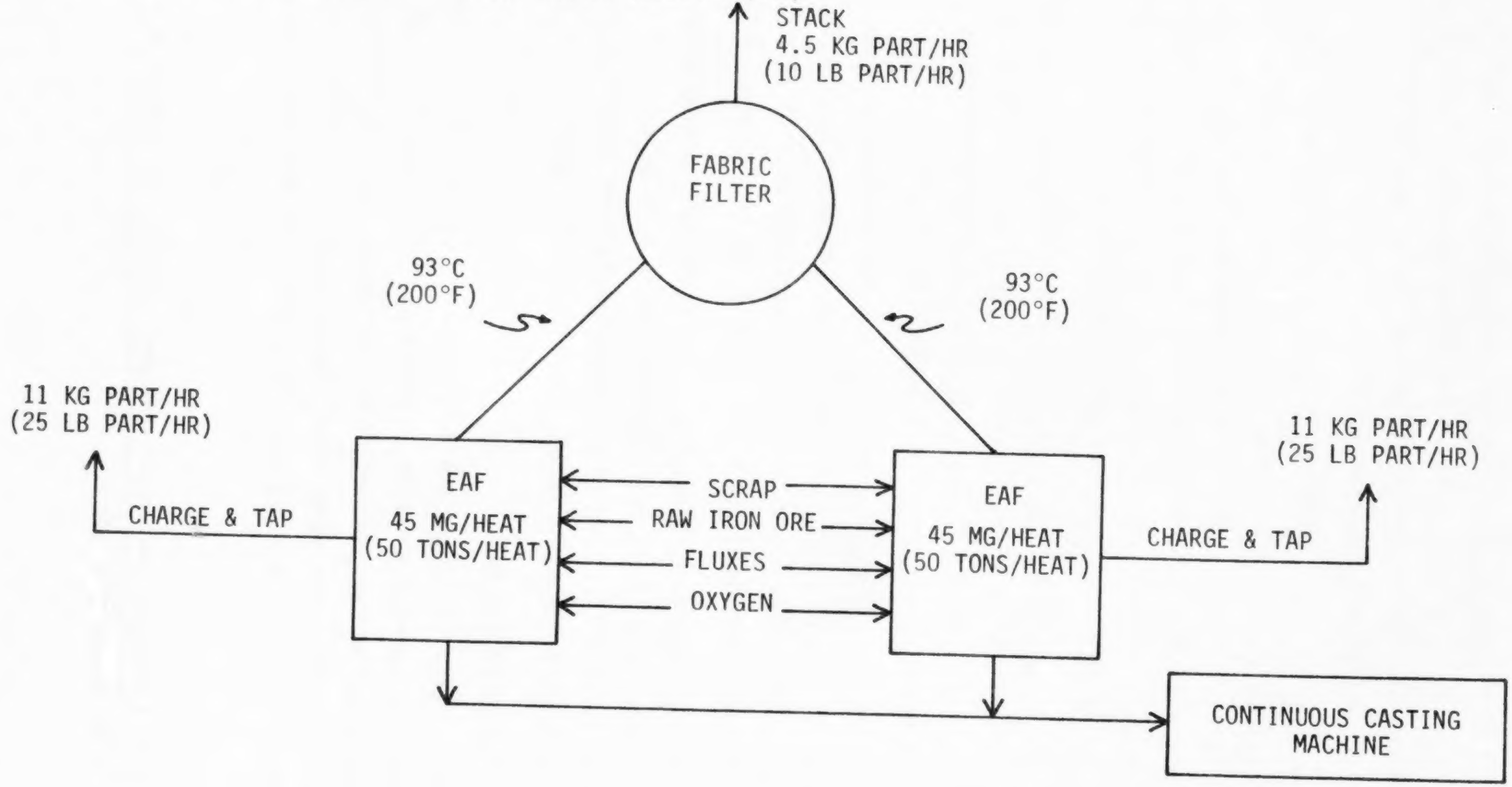
STACK
4.5 KG PART/HR
(10 LB PART/HR)
FABRIC FILTER
93°C
(200°F)
93°C
(200°F)
11 KG PART/HR
(25 LB PART/HR)
CHARGE & TAP
EAF
45 MG/HEAT
(50 TONS/HEAT)
SCRAP
RAW IRON ORE
FLUXES
OXYGEN
EAF
45 MG/HEAT
(50 TONS/HEAT)
CHARGE & TAP
11 KG PART/HR
(25 LB PART/HR)
CONTINUOUS CASTING MACHINE

Figure 4.6-11 Illustration of process and material flows for a model mini-medi mill.

TABLE 4.6-4a SUMMARY OF PARTICULATE AND CADMIUM EMISSIONS FROM MODEL PLANTS (Metric units)

Model plants and facilities	Particulate emissions				Implied collection efficiency[a] (%)	Cadmium Emissions			
	Uncontrolled		Existing control			Uncontrolled		Existing control	
	Kg/hr	Mg/yr	Kg/hr	Mg/yr		Kg/hr	Mg/yr	Kg/hr	Mg/yr
(1) Integrated Steel Mill									
Coke facility	378	3,311	220	1,918	100	0.06	0.54	Tr	Tr
Sinter facility	833	7,297	75	657	91	0.1	0.88	0.009	0.08
Blast furnace shop	88	771	90	771	100	0.06	0.49	Tr	Tr
BOF shop	3,125	27,375	126	1,095	96	0.35	3.07	0.014	0.12
EAF shop	1,567	13,727	47	412	97	0.17	1.49	0.005	0.04
OH shop	620	5,431	31	272	95	0.9	7.88	0.045	0.39
Miscellaneous sources	208	1,822	156	1,366	25	--	--	--	--
TOTAL	6,819	59,734	741	6,491		1.64	14.35	0.073	0.63
(2) Non-Integrated Steel Mill									
Blast furnace shop	88	771	90	771	100	0.06	0.49	Tr	Tr
BOF shop	3,125	27,375	126	1,095	96	0.35	3.07	0.014	0.12
EAF shop	1,567	13,727	47	412	97	0.17	1.49	0.005	0.04
Miscellaneous sources	208	1,822	156	1,366	25	--	--	--	--
TOTAL	4,988	43,695	416	3,644		0.58	5.05	0.019	0.16
(3) Mini-Medi Steel Mill									
EAF shop	900	7,884	27	236	97	0.10	0.85	0.003	0.023
Miscellaneous sources	208	1,822	156	1,366	25	--	--	--	--
TOTAL	1,108	9,706	183	1,602		0.10	0.85	0.003	0.023

[a] Collection efficiency is derived from national control efficiencies presented in Table 4.6-2.

Tr = Trace

TABLE 4.6-4b SUMMARY OF PARTICULATE AND CADMIUM EMISSIONS FROM MODEL PLANTS
(English units)

Model plants and facilities	Particulate emissions				Implied collection efficiency[a] (%)	Cadmium emissions			
	Uncontrolled		Existing control			Uncontrolled		Existing control	
	Lb/hr	T/yr	Lb/hr	T/yr		Lb/hr	T/yr	Lb/hr	T/yr
(1) Integrated Steel Mill									
Coke facility	831	3,640	482	2,111	100	0.14	0.61	Tr	Tr
Sinter facility	1,844	8,077	166	727	91	0.22	0.96	0.02	0.09
Blast furnace	195	854	195	854	100	0.12	0.55	Tr	Tr
BOF shop	6,900	30,222	276	1,209	96	0.75	3.28	0.03	0.13
EAF shop	3,467	15,185	104	456	97	0.33	1.45	0.01	0.04
OH shop	1,380	6,044	69	302	95	2.0	8.76	0.1	0.44
Miscellaneous sources	459	2,010	344	1,507	25	--	--	--	--
TOTAL	15,076	66,032	1,636	7,166		3.56	15.61	0.16	0.70
(2) Non-Integrated Steel Mill									
Blast furnace shop	195	854	195	854	100	0.12	0.55	Tr	Tr
BOF shop	6,900	30,222	276	1,209	96	0.75	3.28	0.03	0.13
EAF shop	3,467	15,185	104	456	97	0.33	1.45	0.01	0.04
Miscellaneous sources	459	2,010	344	1,507	25	--	--	--	--
TOTAL	11,021	48,271	919	4,026		1.20	5.28	0.04	0.17
(3) Mini-Medi Steel Mill									
EAF shop	2,000	8,760	60	263	97	0.19	0.94	0.004	0.025
Miscellaneous sources	459	2,010	344	1,507	25	--	--	--	--
TOTAL	2,459	10,770	404	1,770		0.19	0.94	0.004	0.025

[a] Collection efficiency is derived from national control efficiencies presented in Table 4.6-2.

Tr = Trace

The compliance status of the iron and steel industry was reported by the Council on Environmental Quality for the year 1980.[11] Thirteen percent of the integrated steel plants in the U.S. are in compliance with air pollution regulations. Another 32 percent are in violation of existing standards but are meeting a compliance schedule. About 71 percent of other I&S mills are in compliance with air pollution regulations.*

4.6.7 Comparison of National Emission Estimates with Other Studies

The results of this study indicate that 340.2 Mg (376 tons) of cadmium are introduced into iron and steel manufacturing processes each year and that 25.4 Mg (28 tons) of cadmium are emitted from the I&S industry into the atmosphere each year. Previous studies differ with these estimates of the quantity of cadmium flowing into the industry and the quantity of cadmium emitted. The differences between the estimates of cadmium emissions in this study and the estimates of cadmium emissions in previous studies are discussed below.

This study used recent estimates of the cadmium content of the input materials for the I&S industry. National consumption rates of raw materials published by the American Iron and Steel Institute were also used. Cadmium emissions for this study considered emissions from all sources including coking, sintering, blast furnaces, BOFs, EAFs, OH furnaces, and iron foundries.

In previous studies, cadmium emissions from the steel industry were estimated to be 907 Mg (1000 tons) by Davis and Mitre, 363 Mg (400 tons) by GCA in 1974, about 100 Mg (110 tons) by ORNL, 71 Mg (79 tons) by EPA in 1971, 9.5 Mg (10.5 tons) by EPA in 1975, and 51 Mg (56 tons) by EEA in 1979.[12] The difference between the estimates of these studies and the estimate of this study can be attributed to several factors. Different estimates of raw material usage and the cadmium content of scrap metal were used. The other studies assumed no control or control efficiencies other than the control efficiencies assumed by this study. Other studies failed to account for cadmium emissions from all the processes which this study addressed.

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*This is not a record for compliance or enforcement purposes. This information documents data used in decision making by the Environmental Protection Agency in response to Section 122 of the Clean Air Act Amendments of 1977.

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5. AMBIENT CADMIUM CONCENTRATIONS

5.1 INTRODUCTION

This section examines predicted and measured ambient cadmium concentrations associated with the major cadmium emission sources and primary pyrometallurgical cadmium production. Initial analyses based on annual cadmium emissions indicated that a clear distinction exists between the major sources and the minor sources. Although primary pyrometallurgical cadmium production is considered a minor cadmium emission source based on annual cadmium emissions at 1.3 Mg/yr (1.4 t/yr), the high cadmium content of the emission streams could produce high ambient cadmium levels in the vicinity of the sources.

Ambient cadmium concentrations associated with the major cadmium emission sources were screened using a surrogate pollutant approach which is described in detail in Section 5.2. The purpose of this screening was to identify those source categories with the potential to produce the largest ambient cadmium concentrations if their emissions of cadmium were solely restricted by the existing National Ambient Air Quality Standards (NAAQS) for particulate and lead. The following source categories were screened: municipal incinerators, package incinerators, sludge incinerators, residual fuel oil combustion, coal combustion, primary zinc smelters, primary copper smelters, primary lead smelters, electric arc furnaces, basic oxygen furnaces, blast furnaces, open hearth furnaces, sintering, and coke ovens.

In addition to the two primary pyrometallurgical cadmium smelters, dispersion modeling was also conducted for the two source categories, primary zinc smelters and package incinerators, for which the ambient cadmium concentrations predicted by the surrogate pollutant approach were greatest. This dispersion modeling was based on site-specific stack parameters, terrain, and meteorological data. Two additional dispersion models were performed on the interaction of six primary copper smelters in Arizona and the fossil fuel-fired power plants and municipal incinerators in the New York City-northern New Jersey metropolitan area. The dispersion modeling conducted in this study is presented in Section 5.3.

5.2 SCREENING

A surrogate pollutant approach was used to screen the major cadmium emission sources for their potential contribution to ambient cadmium concentrations. This approach assumes that a particular source is the only contributor to ambient air concentrations of particulate and lead and that emissions from that source are limited solely by the NAAQS's for those pollutants. Under these assumptions, the maximum ambient cadmium concentration limited by existing NAAQS's would be the lesser of the cadmium to lead ratio times the lead NAAQS or the cadmium to particulate ratio times the NAAQS for particulate. Average and maximum cadmium to lead and cadmium to particulate ratios determined from stack tests on the major sources are presented in Table 5.2-1. The product of these ratios and the respective NAAQS's for particulate or lead are also reported in the table as potential ambient cadmium concentrations. The NAAQS for particulate is 75 $\mu g/m^3$, annual geometric mean; the NAAQS for lead is 1.5 $\mu g/m^3$, maximum arithmetic mean averaged over a calendar quarter. Under existing State regulations particulate and lead emissions from individual sources are regulated to levels considerably less than those which would result in ambient levels equal to the NAAQS's. Thus, the ambient cadmium concentrations listed in Table 5.2-1 are upper limits to ambient cadmium concentrations which could result from individual cadmium emission sources in each category.

5.3 DISPERSION MODELING

This section presents results of dispersion modeling performed on four site-specific sources and two interactions of a number of sources.

The Industrial Source Complex Model (ISC)[1,2] Long Term version was chosen as the most appropriate model to use for the dispersion modeling because available meteorological data for locations to be modeled were available in STAR format which is compatible with this model. STAR format is the statistical frequency distributions on wind speed, direction, and stability class for a period of time.

5.3.1 Site-Specific Modeling

The three sources categories with the highest potential ambient cadmium concentrations are primary pyrometallurgical cadmium smelting, primary pyrometallurgical zinc smelting, and package incinerators. In order to give

TABLE 5.2-1 POTENTIAL AMBIENT CADMIUM CONCENTRATIONS PREDICTED BY THE SURROGATE POLLUTANT APPROACH

Source	Average Cd/Pb	Maximum Cd/Pb	Average Cd/Part	Maximum Cd/Part	Potential ambient cadmium concentration (ng/m³) based on				Highest potential cadmium concentration (ng/m³)
					Average Cd/Pb	Maximum Cd/Pb	Average Cd/Part	Maximum Cd/Part	
Municipal incinerators	0.018	0.025	0.0015	0.019	27	38	113	142	38
Package incinerators	0.36	0.55	0.017	0.029	540	825	1,275	2,175	825
Sludge incinerators	0.06	11.6	0.00038	0.0017	90	17,400	28	128	128
Residual fuel oil combustion	0.65	a	2.2×10^{-6}	a	976	a	0.2	a	0.2
Coal combustion	0.10	0.28	7.1×10^{-5}	2.5×10^{-4}	150	420	5	19	19
Primary copper smelting	0.28	0.86	8.4×10^{-4}	2×10^{-3}	420	1,290	63	150	150
Primary lead smelting	0.076	0.095	8.8×10^{-3}	9.6×10^{-3}	114	143	660	720	143
Primary zinc smelting	b	1.3	b	0.061	b	1,950	b	4,600	1,950
Electric arc furnaces	0.018	0.022	4.5×10^{-5}	7.5×10^{-4}	27	33	3	56	33
Basic oxygen furnaces	0.017	0.031	4.5×10^{-5}	8.0×10^{-5}	26	47	3	6	6
Blast furnaces	0.016	0.029	2×10^{-7}	a	24	44	0.02	a	44
Open hearth furnaces	0.011	0.021	4.5×10^{-5}	2.5×10^{-4}	17	32	3	19	19
Sintering	0.04	0.55	6.8×10^{-7}	1.3×10^{-5}	60	83	0.05	1	1
Coke ovens	0.33	a	3.2×10^{-7}	7.9×10^{-7}	50	a	0.02	0.05	0.05

[a] Only one value was found.

[b] Only one value was found but probably represents a maximum

realistic estimates to the ambient cadmium concentrations associated with these categories, dispersion modeling was conducted with site-specific source parameters, meteorological data, and terrain features.

5.3.1.1 Pyrometallurgical Cadmium Plants Two primary pyrometallurgical cadmium plants were modeled during this study: The New Jersey Zinc Co. in Palmerton, Pa. and AMAX, Inc. in Sauget, Il. The New Jersey Zinc Co. was chosen because it is somewhat of a unique case in that zinc production at this plant has ceased operation. However, substantial stockpiles of zinc plant baghouse dust is currently being utilized to produce cadmium. This operation operates continuously and is expected to continue for an indefinite period of time. The AMAX, Inc. plant was chosen because it as considered more typical of pyrometallurgical cadmium smelters.

The parameters used for modeling the two cadmium emission sources at the New Jersey Zinc Co. are presented in Table 5.3-1. The two sources are the cadmium distillation furnaces and the fume kiln.

TABLE 5.3-1. SOURCE PARAMETERS FOR DISPERSION MODELING OF THE NEW JERSEY ZINC CO. PYROMETALLURGICAL CADMIUM PLANT

Stack 1: Cadmium Distillation Furnaces

Stack height = 8.5 m
Stack diameter = 0.3 m
Stack temperature = 322 K
Stack velocity = 9.7 m/s
Cadmium emission rate = 0.017 g/s

Stack 2: Fume kiln

Stack height = 92 m
Stack diameter = 3.7 m
Stack temperature = 355 K
Stack velocity = 1.2 m/s
Cadmium emission rate = 0.028 g/s

The maximum cadmium concentration predicted by ISC is 261 ng/m^3. Table 5.3-2 lists the ten highest annual ground level concentrations as predicted by ISC.

TABLE 5.3-2. TEN HIGHEST ANNUAL CADMIUM CONCENTRATIONS PREDICTED BY ISC FOR THE NEW JERSEY ZINC COMPANY PYROMETALLURGICAL CADMIUM PLANT

Distance from stack (m)	Cadmium Concentration (ng/m^3)
150	261
200	252
125	245
200	204
150	199
300	195
125	179
300	167
200	152
150	151

As Table 5.3-2 indicates the maximum annual cadmium concentration as determined by the model is 261 ng/m^3. Almost all of the ambient cadmium is the result of the emissions from stack 1 which serves the cadmium distillation furnaces. For the purpose of dispersion modeling, it was assumed that all of the particulate emissions from these two stacks is cadmium oxide. The emission rate was corrected to account for only the cadmium portion of the cadimum oxide. There are no ambient cadmium concentration data which reflect the recent shutdown of the zinc operations at this plant.

The parameters used for modeling the cadmium retort furnaces at the AMAX, Inc. plant are presented in Table 5.3.3.

TABLE 5.3.3 SOURCE PARAMETERS FOR DISPERSION MODELING OF THE AMAX, INC. PYROMETALLURGICAL CADMIUM PLANT

Cadmium Retort Furnaces

Stack height = 7.6 m
Stack diameter = 0.6 m
Stack temperature = 389 K
Stack velocity = 17 m/s
Cadmium emission rate = 0.03 g/s

The maximum annual cadmium concentration predicted by ISC is 152 ng/m^3. Table 5.3-4 lists the ten highest annual ground level concentrations as predicted by ISC.

TABLE 5.3-4. TEN HIGHEST ANNUAL CADMIUM CONCENTRATIONS PREDICTED BY ISC FOR AMAX, INC. PYROMETALLURGICAL CADMIUM PLANT

Distance from stack (m)	Cadmium concentration (ng/m^3)
275	152
500	145
225	146
1000	73
160	70
275	68
500	66
275	64
500	62
500	57

As Table 5.3-4 indicates the maximum annual cadmium concentration as determined by the model is 152 ng/m^3. There are no ambient cadmium data with which to compare the results of this dispersion modeling.

5.3.1.2 Pyrometallurgical Zinc Plant. The primary pyrometallurgical zinc smelter chosen for dispersion modeling is the St. Joe Minerals Corporation, located in Monaca, Pennsylvania. Table 5.3-5 presents the source parameters used for the dispersion modeling. Because the plant is located in a river valley, 128 receptor point elevations were selected from topographical maps of the area and entered into the model.

TABLE 5.3-5. SOURCE PARAMETERS FOR DISPERSION MODELING OF A PRIMARY PYROMETALLURGICAL ZINC SMELTER

Stack height = 122 m
Stack diameter = 5.5 m
Stack temperature = 394 K
Stack velocity = 4.9 m/s
Cadmium emission rate = 0.48 g/s

The maximum annual cadmium concentration predicted by ISC is 108 ng/m^3. Table 5.3-6 lists the ten highest annual ground level cadmium concentrations as predicted by ISC.

TABLE 5.3-6 TEN HIGHEST ANNUAL CADMIUM CONCENTRATIONS PREDICTED BY ISC FOR A PRIMARY PYROMETALLURGICAL ZINC SMELTER

Distance from stack (m)	Cadmium concentration (ng/m^3)
1500	108
2000	88
1500	67
2000	64
2000	57
3000	52
2000	46
2000	43
1500	42
1000	41

As Table 5.3-6 indicates, the maximum annual cadmium concentration as determined by the model is 108 ng/m^3. The maximum concentration predicted by the surrogate pollutant approach is 1950 ng/m^3. There are no ambient cadmium data measured in the vicinity of this plant with which to compare the results of either of the dispersion modeling or the surrogate pollutant approach.

5.3.1.3 Package Incinerator. The second cadmium emission source which was modeled on a site-specific basis is a large multiple package incinerator plant, located in Orlando, Florida. This site was chosen because it is one of the two largest package incinerators in the United States. The terrain in Orlando is flat allowing all the elevations at the 102 receptor points to be zero. Meteorological data in the STAR format for Orlando, Florida were used in the ISC Long Term version for the dispersion modeling of this source. The package incinerator located in Orlando is composed of eight 27.2 Mg (30 ton) per day units. A similar but smaller unit was tested in Salem, Virginia by EPA. The stack paramaters, excluding the emission rate, from the Salem unit were used during the modeling. The emission rate was calculated by applying the cadmium emission factor, developed from the results of the Salem tests, to the design production rate of the Orlando unit. Table 5.3-7 presents the source parameters used during the dispersion modeling of the Orlando package incinerator. A single composite stack was used to represent all cadmium emissions.

TABLE 5.3-7 SOURCE PARAMETERS FOR DISPERSION MODELING OF A LARGE PACKAGE INCINERATOR

Stack height	=	12.19 m
Stack diameter	=	1.07 m
Stack temperature	=	480 K
Stack velocity	=	6.31 m/s
Cadmium emission rate	=	0.044 g/s

The maximum annual cadmium concentration predicted by ISC is 60 ng/m^3. Table 5.3-8 lists the ten highest annual ground level cadmium concentrations as predicted by ISC.

TABLE 5.3-8 TEN HIGHEST ANNUAL CADMIUM CONCENTRATIONS PREDICTED BY ISC FOR A LARGE PACKAGE INCINERATOR

Distance from stack (m)	Cadmium concentration (ng/m^3)
1000	60
1000	49
1000	49
1000	46
250	40
1000	37
250	36
250	35
1000	33
2000	31

As Table 5.3-8 indicates, the maximum annual cadmium concentration as determined by the model is 60 ng/m^3. The maximum concentration predicted by the surrogate pollutant approach is 825 ng/m^3. There are no ambient cadmium data measured in the vicinity of this incinerator with which to compare the results of either ambient concentration prediction methods.

5.3.2 Interactions

To estimate potential ambient cadmium concentrations resulting from a number of cadmium emission sources in an area, dispersion modeling was performed on six copper smelters in Arizona and the fossil fuel-fired power plants and municipal incinerators in the New York City-northern New Jersey metropolitan area.

5.3.2.1 Six Copper Smelters. Six of the seven primary copper smelters in Arizona were chosen for modeling because this part of the country has the highest population of primary nonferrous smelters and emissions data had already been gathered and analyzed. The seventh plant was not modeled because all process emissions at the plant are controlled with acid plants and thus cadium emissions from this plant are negligible. STAR meteorological data was available for Tucson, Arizona which is near the middle of the six smelters.

TABLE 5.3-9 SOURCE PARAMETERS FOR DISPERSION MODELING OF SIX PRIMARY COPPER SMELTERS IN ARIZONA

Plant	Stack no.	Stack height (m)	Stack diameter (m)	Stack temperature (K)	Stack velocity (m/s)	Cadmium emission rate (g/s)
Phelps Dodge Douglas, AZ	1	73.2	6.9	445	7.8	0.0277
	2	85.0	5.5	417	9.1	0.172
Phelps Dodge Ajo, AZ	3	69.8	4.8	389	10.8	0.058
Phelps Dodge Morenci, AZ	4	184	7.6	514	5.9	0.116
	5	184	7.4	344	7.2	0.0492
Magma Copper San Manuel, AZ	6	157	6.3	515	11.8	0.0231
Asarco Hayden, AZ	7	305	5.2	369	23.0	0.010
Kennecott Hayden, AZ	8	183	5.2	422	1.5	0.0018

The six smelters and the source parameters used during this modeling are presented in Table 5.3-9. Because of the relatively high stacks and the large distances between the smelters, the terrain impact of the 424 receptor points was not taken into consideration. Two plants, Phelps Dodge in Douglas and Phelps Dodge in Morenci, have two stacks emitting cadmium. This brought the total number of stacks to eight at six plants.

Table 5.3-10 presents the maximum annual ambient cadmium concentrations for each of the six primary copper smelters in Arizona as predicted by ISC.

The ten highest annual cadmium concentrations from the interaction of all six of the primary copper smelters ranged from 1.97 ng/m^3 to 1.18 ng/m^3. The receptor points where these ten maximum values occured are the same ten receptor points where the ten highest cadmium concentrations occured for the Phelps Dodge smelter in Douglas. The surrogate pollutant approach predicted a maximum annual cadmium concentration of 150 ng/m^3, while ISC predicted a maximum annual cadmium concentration for a single smelter of 1.94 ng/m^3. There are some measured ambient cadmium data for this area although most do not meet Storage and Retrieval of Aerometric Data System (SAROAD) qualifications. There is, however, one site in Tucson which did meet the SAROAD qualifications during 1977. This site averaged 5 ng/m^3 over 30 samples using emission spectroscopy as the analysis method and high volume air samplers as sampling method. Although the other sites in Tucson and Phoenix did not meet the SAROAD qualifications for some reason, the values have been incorporated into the SAROAD system. The values are in the range 1 to 2 ng/m^3 and were measured between 1977 and 1980.

TABLE 5.3-10 MAXIMUM ANNUAL CADMIUM CONCENTRATIONS PREDICTED BY ISC FOR THE SIX COPPER SMELTERS IN ARIZONA

Plant	Location	No. of stacks	Maximum cadmium concentration (ng/m^3)
Phelps Dodge	Douglas	2	1.94
Phelps Dodge	Ajo	1	0.97
Phelps Dodge	Morenci	2	0.43
Magma Copper	San Manuel	1	0.04
Asarco	Hayden	1	0.01
Kennecott	Hayden	1	0.02

5.3.2.2 Power Plants and Municipal Incinerators. The second interaction involved the New York City-northern New Jersey metropolitan area. This metropolitan area was chosen to model because it contains 13 oil-fired power plants and three conventional municipal incinerators with a total of 32 discrete emission points. Stacks at the power plants were combined into a single source if the stack parameters were identical or very similar to each other. Stacks were combined only within the power plant itself. An array of 1098 receptor points was chosen from a previous trace metal study of the same area.[3] The terrain for this dispersion modeling was assumed to be flat. Table 5.3-11 presents the sources and the parameters used during the dispersion modeling. New York City meteorological data in the STAR format was used for this modeling.

The 16 plants (13 power plants and 3 incincerators) were modeled to show the annual cadmium concentrations not only from each plant but also from the combination of all plants. Table 5.3-12 presents the maximum annual cadmium concentrations for each of the 16 plants as predicted by ISC.

The ten highest annual cadmium concentrations from the interaction of all 32 point sources ranged from 11.7 ng/m^3 to 9.6 ng/m^3. No direct correlation between these ten highest concentrations and the ten highest concentrations from any particular plant seems apparent. However, the two highest values of the interaction occur at the same receptor point as do the two highest values of the Sayreville plant.

There are some measured ambient cadmium data for this metropolitan area although not all meet the SAROAD qualifications. There is one ambient monitoring site in New York City and six in northern New Jersey. Special discrete receptor points were located at the New Jersey ambient monitoring sites during the dispersion modeling. Table 5.3-13 presents a summary of the measured ambient cadmium data and the ambient cadmium concentrations predicted by ISC.

In a recent study for EPA Region II,[3] dispersion modeling using ISC Long Term version was conducted on 32 proposed or partially built refuse, sludge and coal combustion sources. The receptor points used in Region II study are identical to those used in this study of existing sources. The ten highest cadmium concentrations predicted to occur as a result of these new sources ranged from 80 ng/m^3 to 56 ng/m^3. These ten values represent the highest values predicted to occur at ten of the 1098 receptor points. The average increase in the ambient cadmium concentration is considerably less than this.

TABLE 5.3-11 SOURCE PARAMETERS FOR DISPERSION MODELING OF THE NEW YORK CITY - NORTHERN NEW JERSEY METROPOLITAN AREA

Plant	Stack no.	Stack height (m)	Stack diameter (m)	Stack temperature (K)	Stack velocity (m/s)	Cadmium emission rate (m/s)
Power plants						
59th Street	1	75.6	4.6	422	4.1	0.011
	2	74.9	4.6	505	2.0	0.016
	3	161	5.7	461	2.7	0.018
74th Street	4	158	5.5	505	2.4	0.023
Arthur Kill	5	152	5.9	400	11.8	0.049
	6	152	5.9	400	16.7	0.064
Astoria	7	96.0	4.2	421	12.5	0.024
	8	91.1	4.2	417	12.5	0.024
	9	91.1	6.1	411	11.9	0.048
	10	91.1	6.1	411	12.3	0.10
East River	11	115.2	6.7	477	0.8	0.024
	12	115.2	6.7	533	2.1	0.043
	13	115.2	6.7	435	3.8	0.037
Ravenswood	14	157	4.1	414	29.0	0.114
	15	157	7.3	466	1.1	0.129
Sayreville	16	42.1	2.3	464	1.9	0.013
	17	45.7	3.7	454	7.2	0.020
	18	67.4	3.5	436	16.6	0.020
Werner	19	42.1	3.1	533	7.2	0.003
	20	64.0	3.7	439	8.2	0.006
Bergen	21	93.3	3.5	405	38.7	0.040
Hudson	22	99.4	4.3	417	29.7	0.052
	23	151.8	5.3	411	34.6	0.077
	24	68.0	4.8	422	0.90	0.004
Kearny	25	84.1	4.3	441	14.1	0.041
Linden	26	68.6	3.8	400	14.3	0.050
	27	68.6	3.8	403	29.7	0.034
Sewaren	28	68.6	3.7	419	16.0	0.068
	29	99.1	3.7	375	33.2	0.046
Incinerators						
Betts	30	99.1	3.7	375	7.6	0.023
S. Brooklyn	31	73.0	3.5	727	7.6	0.023
Greenpoint	32	61.0	3.3	505	7.6	0.023

TABLE 5.3-12 MAXIMUM ANNUAL CADMIUM CONCENTRATIONS PREDICTED BY ISC FOR THE SIXTEEN PLANTS IN THE NEW YORK CITY - NORTHERN NEW JERSEY METROPOLITAN AREA

Plant	No. of stacks	Maximum cadmium concentration (ng/m^3)
Power plants		
59th Street	3	1.9
74th Street	1	0.3
Arthur Kill	2	0.6
Astoria	4	3.3
East River	2	3.5
Ravenswood	2	2.7
Sayreville	3	9.4
Werner	2	7.3
Bergen	1	0.4
Hudson	3	0.9
Kearny	1	0.9
Linden	2	2.2
Sewaren	2	2.4
Incinerators		
Betts	1	1.1
S. Brooklyn	1	1.3
Greenpoint	1	1.4

TABLE 5.3-13 SUMMARY OF MEASURED AND PREDICTED AMBIENT CADMIUM CONCENTRATIONS IN THE NEW YORK CITY - NORTHERN NEW JERSEY METROPOLITAN AREA

Sampling location	Sampling year	SAROAD qualified	Concentration (ng/m^3) Cadmium measured	Concentration (ng/m^3) ISC
New York City, NY	1978	No	2	
	1979	No	4	
Patterson, NJ	1977	No	3	
	1978	No	1	1.3
	1979	No	2	
Perth Amboy, NJ	1977	Yes	4	
	1978	Yes	3	4.3
	1979	No	6	
Newark, NJ	1977	No	4	
	1978	Yes	3	3.2
	1979	No	9	
Jersey City, NJ	1977	No	4	
	1978	No	3	5.3
	1979	No	3	
Elizabeth, NJ	1977	No	8	
	1978	Yes	3	3.8
	1979	No	8	
Bayonne, NJ	1977	Yes	5	
	1978	Yes	3	5.3
	1979	No	2	

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Appendix A
CALCULATIONS FOR PRIMARY COPPER SMELTERS

A.1 Derivation of cadmium to particulate ratios:

A.1.1 Multihearth roasters/reverberatory furnace with ESP: The ratio for the combined controlled emissions from these processes was determined from the average of stack test reports for ASARCO-Tacoma[1] and Phelps Dodge-Douglas.[2]

ASARCO-Tacoma	3.0×10^{-4}
Phelps Dodge-Douglas	7.7×10^{-4}
Average	5.4×10^{-4}

A.1.2 Reverberatory furnaces with ESP: The ratio for the controlled emissions from reverberatory furnaces is the average of values determined from stack test reports for Phelps Dodge-Morenci[3] and Magma.[4]

Phelps Dodge-Morenci	7.6×10^{-4}
Magma	1.0×10^{-4}
Average	4.3×10^{-4}

Although this ratio was developed from data on green-fed reverbs, it probably adequately represents emissions from calcine-fed reverbs as well, since cadmium concentrations in green feed and calcine do not appear to differ by an appreciable magnitude (see Appendix A.3).

A.1.3 Converters with acid plant: The ratio for converter emissions controlled by an acid plant was determined from stack test data for Magma[4] to be 2.7×10^{-4}. This ratio is specific to converters controlled with single contact acid plants but has been taken to be representative of emissions from double contact acid plants, due to the absence of cadmium emissions data for these plants. This ratio has also been applied to combined roaster and converter off-gases controlled by acid plants in the absence of more specific data. Although test data for the acid plant stack at Phelps Dodge-Morenci are available, this data was not used because the measured emissions include the contribution of uncontrolled secondary converter emissions.

A.2 Derivation of emission factors:

A.2.1 Reverberatory furnances with ESP: The emission factor for reverberatory furnaces controlled by an ESP was determined from data from Phelps Dodge-Morenci. This was the higher of the two factors calculated from data from Phelps Dodge-Morenci[3] and Magma.[4, 5]

	Cadmium emissions rate (#/hr)	Charge rate (t/hr)	Emission factor (#Cd/t charge)
Phelps Dodge-Morenci	0.916	70	1.3×10^{-2}
Magma	0.182	159	1.1×10^{-3}

The associated cadmium to particulate ratio is 7.63×10^{-4}.

A.2.2 Converters with ESP: This emission factor was developed from data from Phelps Dodge-Douglas.[2]

	Cadmium emissions rate (#/hr)	Charge rate (t/hr)	Emission factor (#Cd/t charge)
Phelps Dodge-Douglas	1.37	69	2.0×10^{-2}

The associated cadmium to particulate ratio is 6.1×10^{-3}.

A.2.3 Fugitive emissions: Fugitive emission sources determined to be potentially most significant with repsect to cadmium are: unloading, handling, and storage of ore concentrates; hot calcine discharge from the roaster; matte and slag tapping from the smelting furnace; and secondary converter emissions from skimming holding and pouring of blister copper. Table A.2-1 presents particulate emission factors recently developed from fugitive emission measurements.[6] The average of these values were used in conjunction with cadmium to particulate ratios for uncontrolled process emissions to derive the cadmium emission factors listed in Table A.2-2. These emission factors were then applied to annual blister copper production capacity to estimate the annual cadmium fugitive emissions listed in Table 4.3.3.1. Cadmium emission factors derived from the smelter-specific factors were applied to estimate emissions for those smelters.

A.3 Derivation of cadmium concentrations in smelter feed:

The companies operating the smelters submitted information on concentrate composition to the EPA in 1974 (references 12-15). The reported cadmium concentrations are as follows:

Company	Cadmium Concentration (μg/g) Average	Cadmium Concentration (μg/g) Range	Number of Samples
ASARCO	122	7-1000	33
Kennecott	48	20-100	8
Magma	48	4-100	3
Anaconda	103	10-200	3

TABLE A.2-1. PARTICULATE FUGITIVE EMISSION FACTORS

Process	Smelter	Emission factor (#PM/T Blister Cu)
Calcine discharge	ASARCO-Tacoma	2.62
	Phelps Dodge-Douglas	5.76
Matte Tapping	Phelps Dodge-Ajo	0.54
Converter	Phelps Dodge-Ajo	10.5
	ASARCO-Hayden	19.9

TABLE A.2-2. FUGITIVE CADMIUM EMISSION FACTORS

Process	Fugitive source	Particulate emission factor (#PM/T Blister Cu)	Cd/PM Ratio	Cadmium emission factor (#Cd/T Blister Cu)
Materials handling	Unloading, handling and storage of ore concentrates	1.7×10^{-2}[a]	9.4×10^{-5}[b]	1.6×10^{-6}
Roaster	Calcine discharge	4.2	9.8×10^{-5}[c]	4.1×10^{-4}
Reverberatory furnace	Matte tapping	0.54	8.5×10^{-4}[d]	4.6×10^{-4}
	Slag tapping	0.12[e]	8.5×10^{-4}	1.0×10^{-4}
Converter	Secondary emissions	15.2	2.0×10^{-3}[f]	3.0×10^{-2}

[a] Emission factor from reference 7. This emission factor has a rating of E.

[b] Average cadmium concentration of copper ore concentrates (see Appendix A.3).

[c] Calculated from data on roaster process emissions sampled after cyclones and prior to ESP at a copper smelter in Bor, Yugoslavia (reference 8).

[d] Calculated from data on reverberatory furnace process emissions sampled prior to ESP at Phelps Dodge, Ajo. The ratio was not derived from trace metal analysis of collected particulate but was calculated from two mass emission rates derived from separate stack measurements conducted in a common study (reference 9).

[e] The available data on slag tapping fugitive emissions were not sufficient to directly support an emissions estimate. The data on fugitive arsenic emissions from the ASARCO-Tacoma and Kennecott-Garfield Smelters (reference 10) were used to compute the ratio of slag tapping emissions relative to matte tapping emissions; the higher of the two resultant ratios, 0.23, was then applied to the matte tapping emission factor.

[f] Ratio derived from a fugitive emission test of the converter building at the ASARCO-Tacoma smelter (reference 11).

In addition, composition analysis of smelter feed has been conducted in conjunction with emission testing at specific smelters (references 2, 3, 9, 16). Cadmium concentrations reported are as follows:

Smelter	Material	Cadmium Concentration (μg/g) Average	Range	Number of samples
Kennecott-McGill	Concentrate	18	ND*(3)-47	3
Phelps Dodge-Morenci	Concentrate	300	270-330	3
Phelps Dodge-Douglas	Roaster feed	75	58-99	6
	Calcine	159	63-550	13
Phelps Dodge-Ajo	Concentrate	18	ND*(3)-49	3

*ND - Not detected. The number in parentheses indicates the limit of detectability. This figure was used in calculating the average concentration.

The overall average of cadmium concentrations in copper ore concentrates calculated from these data is 94 μg/g (Range: ND(3)-1000 μg/g).

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2. U.S. Environmental Protection Agency. Emission Testing: Phelps Dodge Copper Smelter, Douglas, Arizona (September 18-23, 1979). Denver, CO. Publication No. EPA-330/2-80-012. April 1980.

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14. Letter and attachments from Staley, E.K. Magma Copper Company to Goodwin, D.R., EPA. July 3, 1974. Ore concentrate data.

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APPENDIX B

CALCULATIONS FOR FUEL COMBUSTION

B.1 Calculation of Cadmium Emissions from Coal Combustion:

Example: Industrial Sector

(143.0 x 10^6 short tons coal)(25.07 x 10^6 Btu/short ton)(1054 J/Btu)

x (31.3 pgCd/J)(10^{-18} Mg/pg) = 118 Mg Cd

For utility sector, heat content of coal is 21.28 x 10^6 Btu/short ton

Coal consumption values taken from Table 4.2-6.

Cadmium emission factors taken from Tables 4.2-1, 4.2-2, and 4.2-3.

B.2 Calculations of Cadmium Emissions from Residual Oil and Distillate Oil Combustion:

Example: Distillate Oil (D.O.), Commercial/Residential Sector

(513 x 10^6 barrels of D.O.)(42 gal/barrel)(7.24 lbs of D.O./gal)

x (0.1 lbs Cd/10^6 lbs of D.O.)(1 short ton/2000 lbs)

= 7.8 short tons of cadmium

For residual oil calculations, 7.88 lbs. of residual oil/gal.

Oil consumption factors taken from Table 4.2-6.

Cadmium concentration factors taken from Tables 4.2-4, and 4.2-5.

B.3 Calculation of Cadmium Emissions from Kerosene, Jet Fuel Aviation Gasoline, and Motor Gasoline Combustion

Example: Motor Gasoline, Transportation Sector

(2529×10^6 barrels of gasoline)(42 gal/barrel)(15 veh-mi/gal)

(2×10^{-8} lb Cd/veh-mi) x (1 short ton/2000 lb) = 16 short tons Cd

For kerosene and jet fuel, emission factor is 7×10^{-7} lb/gal.

Fuel consumption values taken from Table 4.2-6.

Cadmium emission factors taken from EEA report (Reference 5).